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NAVY FLEET EVALUATION OF THE AIRCRAFT SKIN PENETRATOR

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Current Air Force firefighting equipment does now allow quick and easy entry to airframe voids. Fires are frequently located in an enclosed or limited access area, to which entry can be time-consuming, and dangerous, in that creating an opening can increase the intensity of the fire.

Considerable effort has been expended in designing firefighting equipment that can penetrate an aircraft skin and apply a firefighting agent. AMETEK, Inc./ORED designed an aircraft skin penetrator/agent applicator tool which met the requirements specified by the U.S. Air Force and U.S. Navy under Contract F08635-82-C-0472. The tool was tested and evaluated over a 60-day period. This report describes the testing and performance evaluation conducted, and offers recommendations for improvements of the tool and training of firefighting personnel in its use.

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PREFACE

This technical report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, Campus Box 25, Albuquerque, New Mexico 87131, under contract F29601-84-C-0080 (Subtask 3.17), for the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base Florida 32403, and the Naval Air Systems Command, HQ NAVAIR, Washington, DC 20361.

CWO-4 Bobby Barrow was the project officer for HQ AFESC/RDCF and Ms. Phyllis Campbell was the project officer for NAVAIR. This report summarizes work done between July 1985 and December 1986. This report was submitted for publication February 1987.

The assistance of Chief Pete Semanick and the firefighting team at Kirtland Air Force Base, New Mexico is appreciated.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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SECTION I
INTRODUCTION

A. OBJECTIVE

Testing described in this report was designed to evaluate and demonstrate the operation of the skin penetrator/agent applicator tool and facilitate its implementation in fighting aircraft fires.

B. BACKGROUND

Current Air Force firefighting equipment does not allow for quick and easy entry to airframe voids. Fires are frequently located in an enclosed or limited access area. To effectively fight and suppress aircraft fires, firefighters rapidly apply an agent directly to the base of the fire. Testing has shown that even opening an accessible door can increase the intensity of the fire. With the use of high-strength alloys and various aircraft configurations, a forced entry can be time consuming and dangerous.

Considerable effort has been expended in designing firefighting equipment that can penetrate aircraft skin and apply a firefighting agent. Work was done by the U.S. Air Force (Reference 1), the Federal Aviation Administration (Reference 2), the National Aeronautics and Space Administration (Reference 3), and private equipment manufacturers. Previous efforts involved ramming a penetrator tip through the aircraft skin with a slidable mass or a hammering technique. Later studies considered using explosive projectiles to penetrate the aircraft skin. All of these methods required a considerable amount of human muscle power to achieve penetration. Although these tools were sometimes helpful, they did not apply to the large range of situations encountered while fighting aircraft fires.

In 1983 the Air Force Engineering and Services Center (AFESC) and the Naval Air Systems Command (NAVAIR) contracted AMETEK, Inc., Offshore Research and Engineering Division (ORED) to design, build, and test a tool for the penetration of aircraft skin and application of firefighting agents.

The U.S. Air Force and U.S. Navy in Contract F08635-82-C-0472 identified the following requirements for an aircraft skin penetrator/agent applicator tool:

1. Penetration Requirements

The tool shall penetrate aircraft skin materials and any internal thermal or acoustical insulation materials and cabin panels. The penetrator device shall be capable of penetrating a minimum of 14 inches.

2. Mechanical Actuation

The tool shall be mechanically actuated and safe to operate in any explosive or flammable environment. The device shall not incorporate ballistic or explosive propellant materials.

3. Operation by One Person

The tool shall be operated by one person from a variety of positions, from hip-level to overhead at arm's length, and from various footings, including the ground, aircraft surfaces, and a ladder.

4. Halon 1211 Delivery

The tool shall be suitable for delivery of Halon 1211 fire suppression agent.

5. Firefighting Vehicle Base

The tool shall be designed to be fully functional from a firefighting vehicle as the operational base.

6. Quick Disconnect

The tool shall have quick-disconnect capability for both input connection and nozzle output connection.

7. Halon 1211 Discharge Rate

The tool shall be capable of discharging Halon 1211 at 5 to 5.5 lb/s.

8. Throw Range

The tool shall be designed to have an effective agent throw range of not less than 30 feet.

9. Trigger-Type Turn-On

The tool shall have a trigger-type of actuation turn-on.

10. Retention

The tool shall have a suitable retention means to prevent the penetrator from falling out during use if unattended. (Note: Mechanical or nonmechanical means are acceptable.)

11. Human Engineered

The tool shall be human-engineered for operational use by a single firefighter wearing full protective proximity clothing, including gloves, as required for a realistic fire environment.

AMETEK Inc./ORED designed a tool to meet the requirements identified and submitted a report describing the tool (Reference 4). Figure 1 shows the tool finally designed and constructed, which satisfied the design specifications.

C. SCOPE

An extensive evaluation of the tool's performance and how that performance varied with use was conducted. Included was a questionnaire which was completed by the firefighters covering an extended evaluation of the tool's performance. To find an expected life for the penetrator tool, each part of the tool was evaluated.

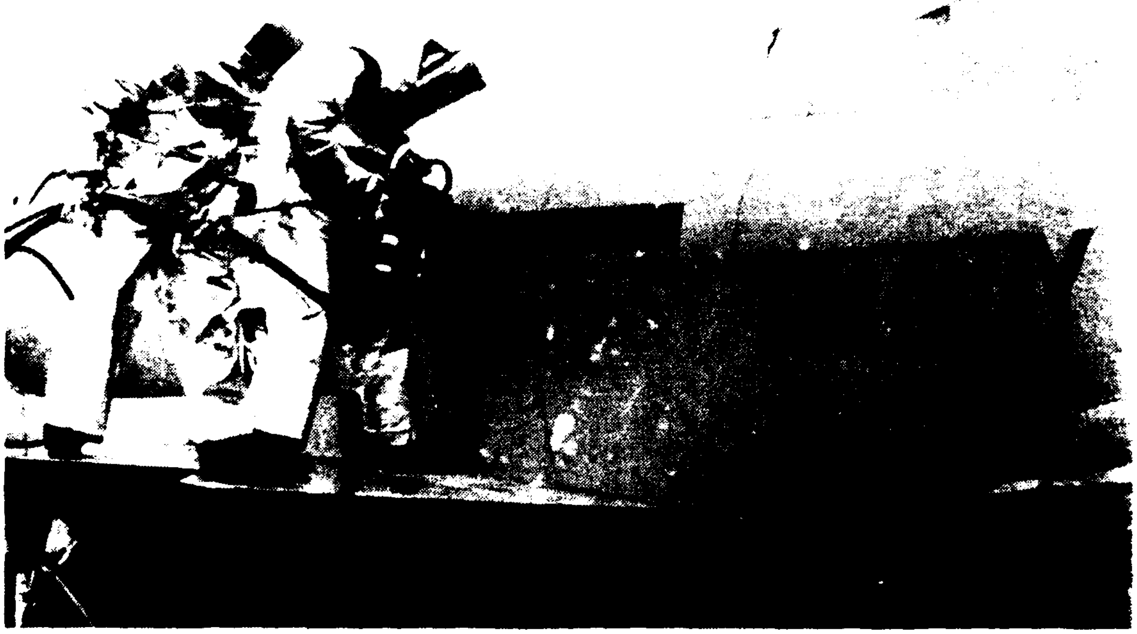

Figure 1. Penetrator Tool Evaluated for Use by the Navy.

The firefighting tool was demonstrated to U.S. Navy, U.S. Marine, and Federal firefighting personnel. In the training sessions the personnel completed a two-part seminar, giving them classroom and field training in the operation of the skin penetrator/agent applicator tool.

SECTION II
PERFORMANCE EVALUATION OF SKIN PENETRATOR

To evaluate the performance of the skin penetrator, a 60-day performance evaluation period was planned and a test plan for evaluation submitted and approved. The approved test plan is contained in Appendix A. The test plan may be divided into four parts. The first part of the test procedure involved an initial inspection of the penetrator as received and an evaluation of the manual for operation and maintenance of the tool. The second part included testing related to drill bit and motor performance. The third part evaluated the firefighting performance of the skin penetrator tool. In the fourth part of the evaluation testing, details of which are reported in later sections of this report, the penetrator tool was evaluated by military and civilian firefighters after they had been instructed in its proper use. Detailed in this section are the evaluation tests outlined under paragraph 2.5 of the Test Plan (Appendix A).

A. INITIAL INSPECTION

Upon arrival of the penetrator tool, the parts were unpacked and inspected for shipping damage. The tool, shown in Figure 2, arrived intact and fully operational with no defects or damage. After inspection of the tool, the operation manual was evaluated for readability, consistency, and order of presentation. Analysis showed few inconsistencies and a well-ordered presentation which can be easily read by military firefighters.

The manual as supplied provides assembly instructions, operating instructions, preventive maintenance instructions, and a section with specific information on subsystems of the skin penetrator tool. In the assembly section every major system is separated and identified. Instructions needed for using the tool, including safety precautions, are in the operating section of the manual. Instructions for reconfiguring the tool for different air sources are also included, as are detailed instructions on how to set up a preventive maintenance system. The importance of preventive maintenance is stressed in the manual, and it is pointed out that faithful use of a maintenance plan will:

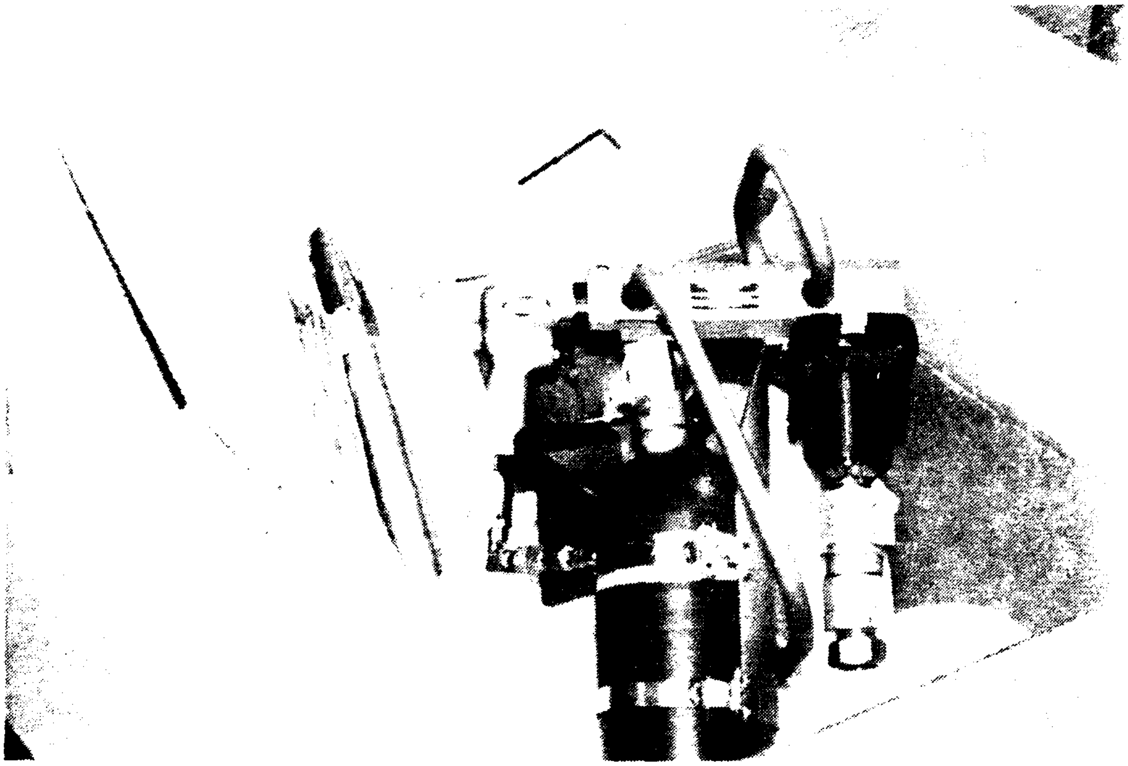

Figure 2. Penetrator Tool as Received.

- reduce downtime,
- reduce the frequency of panic repair situations,
- extend the service life of the equipment, and
- make using the tool safer and easier.

The final section of the manual includes information on the large subsystems and a parts drawing of the skin penetrator tool.

A warning in the front of the operation manual states that the cutting bit is for aluminum skin only and to contact the factory if drilling any other material. The parts list showed no other drill bits available, but the New Mexico Engineering Research Institute (NMERI) was informed that work is being performed on a drill bit that will cut through steel and other materials.

After evaluation of the manual was completed, the tool was assembled and evaluated.

During assembly the only part which produced problems was the tool bit/bushing assembly. A snapring was used to secure a brass bushing which was threaded with left-hand threads into the flow barrel. If the tool bit was damaged, the person who changed the bit would need a pair of snapring pliers. Because damage to the drill bit would most likely occur during a crisis situation, and snapring pliers are an uncommon piece of maintenance equipment, a recommendation was made to AMETEK to supply the tool bit with a preinstalled bushing to alleviate this problem. AMETEK sells a bit assembly with the bushing already installed, although it is not mentioned in the parts list. Preinstallation of the bushing can solve another problem. The manual calls for a 0.15- to 0.30-inch clearance to be maintained during drilling while pressure is being applied to the bit. The problem occurs during removal when the only thing holding the bit into the tool is the snapring. Because of the spacing needed to install the snapring, the clearance between the front of the bushing and the back of the bit is more than doubled when pulling the tool while removing it from a drill site. With the clearance larger than the thickness of the aircraft skin the skin can become lodged between the bit and the bushing, thus, delaying tool removal. With an alternate method of attaching the bushing to the bit shaft, the clearance could be maintained, resulting in reduced operation and assembly problems.

During assembly, all areas of the tool were checked for pressure leaks and sufficient lubrication. After the initial evaluation of the penetrator tool, final assembly of the tool was completed according to directions given in the manual, and the tool was found to perform within specifications.

B. DRILL BIT AND MOTOR EVALUATION

Testing was conducted to evaluate the performance of the drill bit and motor of the penetrator tool. Information collected during this evaluation can be used to assess the service life of the penetrator tool and evaluate problems which might arise during normal operation of the tool. Table 1 contains a list of tests which were performed to evaluate the penetrator tool. To realistically evaluate the penetrator tool drill bit and motor, the tool was tested against five different types of aircraft skin assemblies and against a standard aluminum sheet (described as Panel 1). The six different panels are described as follows:

TABLE 1. TEST PERFORMED DURING DRILL BIT AND MOTOR EVALUATION

Test No.	Title	Test Material
1	Drill bit replacement	None
2	Regulator testing	None
3	Drilling time with self-contained bottle (full speed)	None
4	Drilling time with self-contained bottle (half speed)	None
5	Human/tool interaction evaluation	Panel 4
6	Drill motor rotational speed	None
7	Drill bit wear series, holes 1-4	Panel 1
8	Drill bit wear series, holes 24-27	Panel 1
9	Drill bit wear series, holes 35-37	Panel 1
10	Drill bit wear series, holes 50-52	Panel 1
11	Drill bit wear series, holes 73-75	Panel 1
12	Drilling times and number of penetrations	Panel 2
13	Drilling times	Panel 2
14	Drilling times	Panel 2
15	Drilling times	Panel 3
16	Drilling times and number of penetration on B-52	Panel 4
17	Penetration times ramming skin	Panel 4
18	Drilling times and number of penetrations	Panel 4
19	Drilling times for different configurations	Panel 4
20	Drilling times for overhead drilling	Panel 4
21	Low regulator pressure drilling	Panel 4
22	Drilling time for 0.128-inch section	6061-T6 aluminum
23	Drilling time for 0.125-inch section	6061-T6 aluminum
24	Drilling time for 0.245-inch section	6061-T6 aluminum
25	Drilling time for 0.38-inch section	Aluminum
26	Drilling time for 0.628-inch section	6061-T6 aluminum
27	Drilling time for 1.05-inch	6061-T6 aluminum
28	Drilling time for 55-gallon steel drum	Steel
29	Drilling time for 0.071-inch section	1020 steel
30	Drilling time for 0.184-inch section	1020 steel
31	Final drill motor testing	None
32	Drilling time A-4	Panel 5
33	Drilling time HC-131	Panel 5

Panel 1

Sheet aluminum, 2024-250/4, skin thickness 0.063 inches.

Panel 2

Skin assemblies, aluminum 1560-00-627-0781FG, 5-46496-105, and F34601-76-A-0720-0204-01; skin thickness 0.068 inches.

Panel 3

Skin assemblies, aluminum 1560-508-8234FG and F34601-73-D-0851; skin thickness of outer panels 0.024 inches, aluminum honeycombed 0.001 inches, total thickness 0.025 inches.

Panel 4

B-52 aircraft; aluminum, skin thickness 0.045 inches.

Panel 5

A-4M Skyhawk aircraft; aluminum, skin thickness 0.045 inches.

Panel 6

C-131 aircraft; aluminum, skin thickness 0.056 inches.

Initial performance data were taken using Panel 1 and used as reference points. From these reference points degradation of performance was studied as the tool was used. Information collected was:

- revolutions per minute at various pressures,
- revolutions per minute at full speed and one-half speed,
- time to drill one hole, and
- number of holes per pressure tank.

Revolutions-per-minute data were taken with a digital photoelectric tachometer manufactured by TIF Instruments, Inc. The specifications for the tachometer are:

Range:	15 to 10,000 r/min
Accuracy:	±2 percent
Photocell:	cadmium sulphide

During testing, the self-contained bottles were charged to 2200 lb/in^2. This was done for two reasons: (1) the initial results produced by AMETEK were obtained with a charge pressure 2200 lb/in^2, and (2) because all of the bases have facilities for charging breathing air bottles to 2200 lb/in^2. The self-contained bottles on the pentrator tool have the same fittings and valving as the breathing air bottles. The pneumatic cylinder provided may be charged to a maximum pressure of 3,000 lb/in^2, which would provide the tool with a 26 percent increase in air supply.

The results of the 33 tests performed are discussed briefly below. In some instances the tests are grouped and an overall discussion of information obtained as a result of the testing is given. A detailed description of each of the tests with detailed results and comments is contained in Appendix B.

In Test 1 the amount of time necessary to change the drill bit was determined under field conditions. Because the removal of the bit requires the use of snapring pliers, which are not a standard field tool, the replacement of the bit was not attainable under current field conditions. The results of this test were a reason for recommending to the manufacturer that they redesign the drill bit bushing as described above.

In Test 2 the regulator output as a function of bottle pressure was determined. It was found that there was no deviation from the specified reulator pressure of 100 lb/in^2 as the tank pressure was varied from 2200 lb/in^2 to 250 lb/in^2.

In Tests 3 and 4 the minimum operating time of the drill was determined under no-load conditions at full and half speed. The tool was determined to have expended the portable air charge when the pressure on the regulator dropped below 40 lb/in^2. At full speed the minimum operating time was 40 seconds.

In addition to the information gained during the first four tests, these tests served to familiarize test personnel with the operation of the penetrator tool.

In Test 5 the tool was evaluated for human engineering. The requirement was that the tool be operational by a single firefighter wearing full pro-tective proximity clothing, including gloves. Two configurations of the tool were evaluated: (1) the configuration as received with the self-contained air bottle, and (2) the alternate configuration with the air bottle detached and nitrogen supplied from an external source. Drilling during this evaluation was accomplished on Panel 4 material. It was determined that in the primary configurations with the air bottle attached, the best performance was attained with the tool held at waist level. Figure 3 shows the maximum drilling height obtainable with some control over the tool retained. At this height, the drilling time more than doubled.

With the tool in the alternate configuration, the weight is decreased by 12.8 pounds and the profile of the tool is decreased by 9 inches. This reduction in weight and size greatly increases the maneuverability of the tool. In addition, with the alternate nitrogen source, the amount of material through which the tool can penetrate is increased. The disadvantage of operating the tool in this configuration is that there is no back-up supply of air in case the nitrogen line is ruptured.

During these tests, stalling of the drill motor was a problem. Because of the internal design of air-driven drill motors, they do not produce very much torque and are inefficient users of compressed air. Their main advantages are ease of construction and low cost. To compensate for the low torque that the motor produces, the operator must develop a technique to efficiently drill holes. It is easy to apply too much pressure to the drill bit, causing it to feed too rapidly and stall the motor, which increases the time required to drill a hole. The operator needs to learn to apply enough pressure to load the tool just to the point of stalling the motor but keep the rotational speed to a maximum. Increasing the motor torque would allow more feed pressure to be applied to the drill bit before stalling the motor, thus, greatly reducing the cutting time.

The degradation of the motor with use was evaluated. In Test 6 the motor speed as a function of initial pressure was measured for a new motor. Measurements were taken at both full and half speed. It was found that at the specified pressure the motor speed was less than the rated speed of

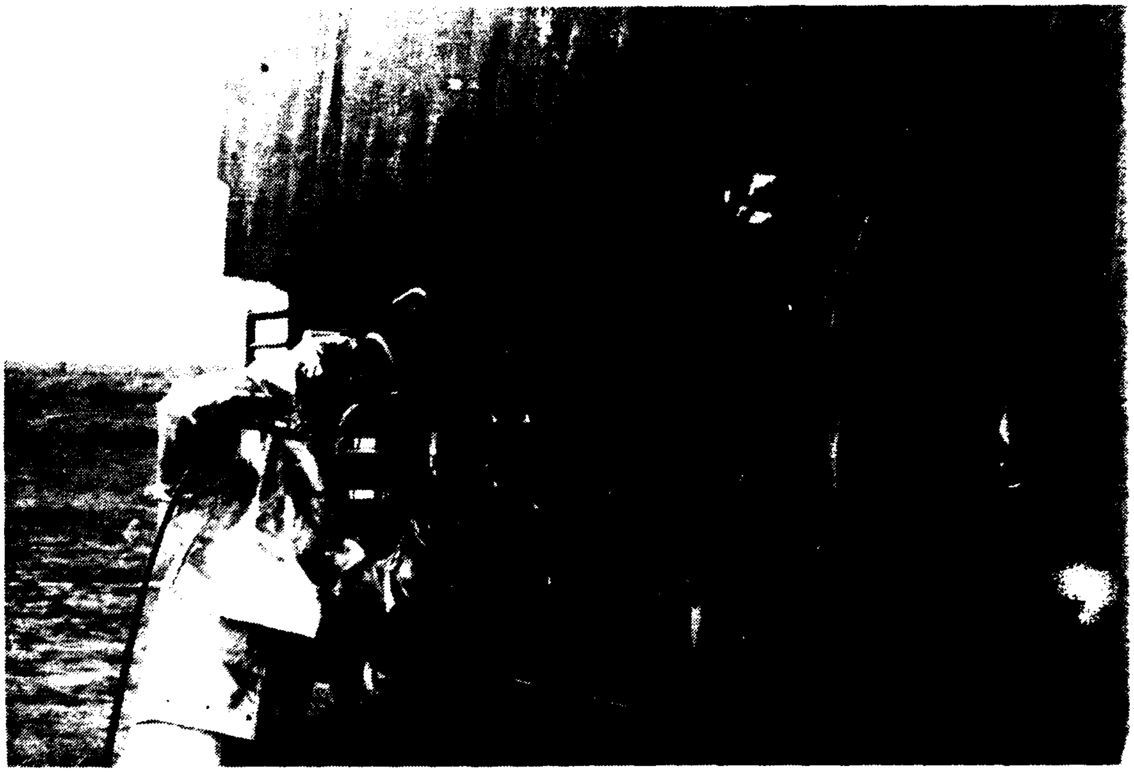

Figure 3. Maximum Height at Which the Penetrator Tool May Be Held While Still Maintaining Effective Control of the Tool.

430 rpm at 90 lb/in^2 (the measured speed being 390 rpm at 90 lb/in^2 (Table B1)). This reduction in motor speed is probably due to the increased load on the motor caused by running the drill bit. The results of Test 6 (Table B1) show that the motor runs more efficiently at full speed than at half speed. This is shown by the fact that a 20-percent drop in pressure at full speed results in a 9-percent decrease in rotational speed, while at half speed a 2-percent drop in pressure results in a 13-percent drop in rotational speed.

To assess the degradation in motor performance as a result of use, the motor speed as a function of initial pressure was determined after approximately 39.7 minutes of drilling time. During the 39.7 minutes of drilling time, more than 100 holes were drilled through a variety of material. The final motor performance tests are documented in Appendix B under Test 31. The results of the final motor performance tests were then compared to the results of initial tests; this comparison is summarized in Table 2. Motor degradation is shown by the overall drop in rotational speed. In view of the large amount of heavy drilling, a maximum 3.7-percent decrease in rotational speed (at full speed) is not excessive.

To assess the degradation of the drill bit that occurs during use, a series of 75 holes was drilled through a section of 2024-250/4 heat-treated aluminum described as Panel 1. The time required to drill tnrough the panel and the total number of holes drilled on a single charge of the self-contained bottle were measured at five intervals described in Appendix B as Tests 7-11. Panel 1 material was chosen because it is one of the best known of the high-strength aluminum alloys. Because of the high strength (tensile strength is 70,000 lb/in^2; yield strength is 50,000 lb/in^2) and excellent fatigue resist-ance of Panel 1 material, it is used to advantage on structures and parts where good strength-to-weight ratio is desired. It is a material commonly used on aircraft and, because it has a known specification, it makes an excellent control material. The results of Tests 7-11 are summarized in Table 3, and testing is shown in Figure 4. The results contained in Table 3 show a 24-percent increase in drill time and a 33-percent decrease in the number of holes drilled over the course of the study.

In Tests 12-14, the time necessary to drill thorugh Panel 2 material was assessed. During Test 12 the drill time increased from 10.6 seconds to 26.1 seconds and the tool operator was unable to complete the second hole. It was noticed at this point that the starting tip on the bit had broken during the drilling of the first hole, which greatly increased the amount of time necessary to drill the second hole. In subsequent tests (13 and 14) the drilling times gradually reduced until they were the same as with a new bit. The subsequent reduction in drill time was because, as drilling continued, small pieces of metal continued to fracture off the heat-treated cobalt tool-steel bit until the starting tip was sharpened. To keep this from recurring, the starting tip would need to be redesigned by making it smaller or angled, thus,better able to withstand the stress generated by drilling of high-tensile-strength aluminum alloy material.

The time required to drill through material described as Panel 3 was an average of 2 seconds (Test 15). This panel had an overall section thickness of 0.258 inches and was constructed of an aluminum foil honeycomb epoxied to

TABLE 2. COMPARISON BETWEEN INITIAL AND FINAL MOTOR TESTS.

Full-Speed			
Regulator Pressure Running, lb/in^2	Initial Average	Final Average	Percent Change
100	403	388	3.7
90	390	378	3.1
Half-Speed			
120	305	290	4.9
105	277	273	1.4
96	265	262	1.1

TABLE 3. RESULTS OF DRILL BIT DEGRADATION STUDY.

Test	Number of Holes[a]	Drill Time[b]
7	3	9.3 seconds average
8	3	10.7 seconds average
9	2	11.5 seconds average
10	2	10.8 seconds average
11	2	12.3 seconds average

[a]Number of holes drilled in the panel with single nitrogen charge.

[b]Time averaged over number of holes drilled.

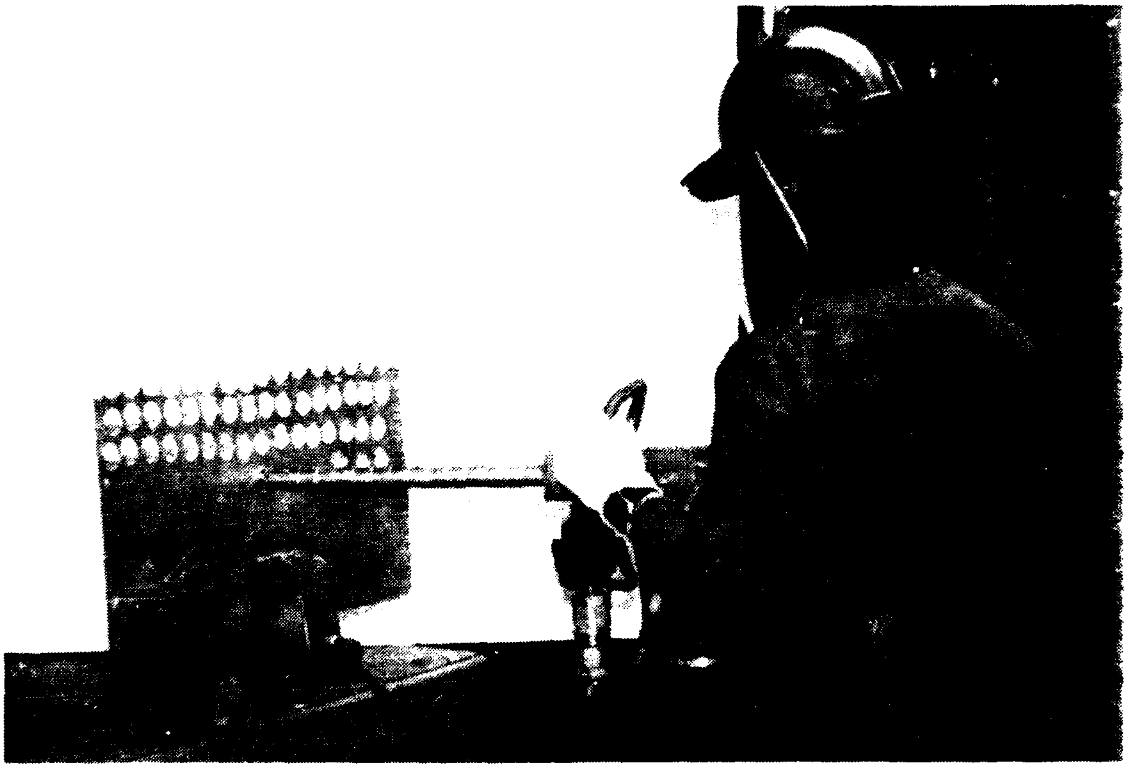

Figure 4. Test Panel Used for Drill Bit Degradation Study.

outer layers of 0.024-inch aluminum sheet. It was observed that the drilling times on multilayer sections depend on the thickness of the heaviest layer.

Tests 16-21 evaluated the amount of time necessary to drill tnrough the material described as Panel 4, which consisted of the front section of a B-52. At the beginning of these tests a new bit was installed in the tool. In Tests 16 and 18, the self-contained air bottle was evaluated and it was found that three holes could be drilled through the material on a single charge of air. The average drill times for 16 holes drilled in Tests 16, 18, and 19 were 11.9 seconds. In Test 17 the penetrator was rammed into the skin of the aircraft while the bit was turing. This resulted in an average penetration time of 3.4 seconds; however, this technique is not suggested, since the resulting holes are rough, with the metal tearing up to 2 inches from the hole. The tearing that occurs when the tool is rammed into the aircraft does not allow the tool to lock itself into the aircraft skin, resulting in the need for the tool to be constantly manned while dispensing agent.

In Test 20 the time required to drill through the Panel 4 material was determined with the penetrator tool being held overhead and the operator's arms fully extended. This position resulted in nearly a threefold increase in the drill time, to 29.1 seconds. This test emphasized the need for proper positioning of the operator during operation of the penetrator tool. To attain proper positioning, the operator will need to be elevated into position. Use of a stepladder is not recommended because the amount of force the operator must exert on the tool to penetrate the aircraft skin would make the stepladder unstable.

The results of Test 21 show that penetration may not be attained at reduced bottle pressures, and that if the regulator pressure is allowed to drop below 40 lb/in^2 effective penetration is not possible.

In Tests 22-27, the amount of time required to drill through various thicknesses of 6061-T6 aluminum plate was determined. These tests showed that the time necessary to penetrate the plate increased from 39 seconds for 0.128-in-thick plate to over 5 minutes for 1.05-inch-thick plate. The air supply for these tests was provided by an external bottle, since the self-contained bottle did not provide sufficient air to complete drilling of the aluminum plate. The starting tip was not very efficient and a large amount of pressure was necessary to drill the material. Once the drill tip was through, the bit had a tendency to cut too much material and stall the drill motor.

Tests 28-30 evaluated the ability of the skin penetrator to drill through steel. Although the bit is not specified for use on steel, these tests were conducted to evaluate the performance of the tool in an emergency situation on nonspecified materials that may be encountered when attempting to penetrate an aircraft fuselage. As with aluminum, if sufficient air supply was available the drill would cut through the material. The drill times ranged from 21 seconds to penetrate the side of a 55-gallon steel drum to 369 seconds to penetrate a 0.184-inch-thick plate of 1020 mild steel. With the higher tensile strength of steel, cutting of the initial hole was difficult and time-consuming. During these tests the drill bit starting tip was broken. The damage to the starting tip emphasizes the need to redesign the starting tip as well as introduce new bits which may prove more effective in the penetration of steel components on aircraft.

Testing was also done to evaluate the tool's performance both on fighter aircraft (Panel 5 material) and cargo aircraft (Panel 6 material). Tests conducted on a Navy A-4 resulted in a penetration time of 13 seconds to penetrate the engine compartment of the aircraft. The operator approached the penetration point on the A-4 from the top of the wing. This testing is shown in Figure 1. The HC-131A was penetrated to the aft of the cargo door and, because of the height of the penetration point, a ladder was used to elevate the operator (Figure 5). Because of the awkward positioning caused by using the ladder, the penetration time increased to 15 seconds.

Figure 5. Penetration of C-131A Aircraft During Evaluation.

C. FIRE TESTING

Fire tests were conducted as part of the orginal development and evaluation of the aircraft skin penetrator tool which demonstrated the perform-ance of the tool under normal operating conditions. As part of the current study, the performance of the tool was evaluated under specialized conditions of fighting a pool fire or a fire in an airframe under conditions of high airflow or increased oxygen concentration. This evaluation included studies of flow rate, throw range, throw pattern, and the effect of tool positioning on t firefighting capability of the penetrator tool.

1. Halon 1211 Flow Rate

One of the design criteria for the penetrator tool was that it be capable of discharging Halon 1211 at a flow rate of 5 to 5.5 lb/s. Flow testing of tne penetrator tool using Halon 1211 supplied from a 150-pound wheeled unit charged to 150 lb/in^2 resulted in a discharge rate 5. lb/s. During testing, agent was discharged for 5 seconds with the nozzle in the full open position, and the initial and final weight of the storage cylinder was recorded. The recorded weight loss was 27.3 pounds, resulting in an agent discharge rate of 5.46 lb/s.

2. Throw Range and Discharge Pattern

Throw range was also of design importance in the construction of the penetrator tool. The original requirement was for an effective throw range of 30 feet when discharging Halon 1211. This throw range is difficult to attain under outdoor conditions because of the effects of wind on throw range, which is especially accute for the penetrator, since there is an increase in gaseous component when discharging Halon 1211 from the penetrator tool.

The increase in gaseous component is primarily caused by the effects of the flow path the agent must take through the tool. Agent flow is initiated by a ball valve located under the main body of the tool next to the penetrator cylinder. After passing through the ball valve, the agent flows into the main body of the tool and turns at a right angle. The flow barrel which houses the drill bit directs the agent to the exit orifices at the end of the flow barrel behind the drill bit. Eight 1/8-inch holes, spaced evenly around the diameter of the flow barrel, direct the agent as it enters or leaves the tool. The holes are drilled at a 30-degree angle to the flow tube. Because of the complex path the agent must follow through the tool, there is a fairly large pressure drop. With Halon 1211 this pressure drop and long path cause the agent to exit the tool with an increased gaseous component, as compared to Halon 1211 discharged from the standard nozzle on the P-13. The resulting discharge pattern is a 40-degree cone of Halon 1211 which collapses into a 4-foot diameter cylinder of Halon 1211 gas. The discharge pattern is shown in Figure 6.

Figure 6. Penetrator Being Used to Extinguish 150 ft^2 Pool Fire.

3. Performance of Tool in the Extinguishment of Pool Fire

The performance of the penetrator tool in the extinguishment of a 150 ft^2 pool fire was evaluated. Fuel was floated on water contained within a 14.5-foot diameter concrete-lined pit. During testing a 3-5 mi/h wind was blowing to the northeast. Thirty gallons of JP-4 jet fuel were preburned for 60 seconds, allowing the fire to reach a steady-state condition before extinguishment was attempted. The extinguishment, shown in Figure 6, required 66 pounds of agent and took 12 seconds. During extinguishment the firefighter experienced difficulties suppressing the fire on the far side of the pool. Upon review of the video of the test it was noticed that a large portion of the agent was being drafted away from the base of the fire by the heat coming off the pool before the agent could reach the far side of the pool. The drafting away of the agent coupled with lip effects of the pool account for the difficulty experienced in the extinguishment of the fire. The test showed that a firefighter could protect himself using the developed penetrator tool while approaching or retreating from a burning aircraft.

4. Effectiveness Under Conditions of High Airflow

The effectiveness of the penetrator tool under conditions of high airflow and increased oxygen concentration was evaluated. To test the potential of the tool, oxygen was supplied to the test fire, thus, approximating a worst-case condition of high airflow with increased oxygen concentration. The actual data collected are reported elsewhere (Reference 5), while what follows is an interpretation of the actual tests in view of the requirements of the present task.

When a fire has burned long enough to burn through the outer skin, the turbulence of the fire is able to supply more combustion air to intensify the fire. The fire becomes a drafting fire, which is very difficult to extinguish because a fresh air supply is being delivered to the fuel surface for combustion. This type of fire was approximated with flowing oxygen. To suppress such a fire, either all of the incoming air needs to be inerted or halon must be injected into the combustion mixing zone at the base of the flames for a short time period.

On a well-established fire, a large amount of air can be drafted past the fire. To inert this would require a very large supply of halon over a long period of time. Military crash rescue vehicles do not carry this amount of agent or even have readily available access to the amount of halon needed; therefore, for a large aircraft fire the standard procedure is to apply large amounts of aqueous film-forming foam (AFFF) to the exterior of the burning aircraft. This procedure extinguishes all of the exterior fires, but the aircraft body blocks and protects the internal fires and the aircraft continues to burn.

Testing was done to determine if the penetrator tool has the ability to inject halon directly to the base of the fire under conditions where air is being drafted into the flow. The drafting of air into the fire was simulated by injecting oxygen into the fire. During testing, Halon 1211 was able to suppress the fire except when the penetrator tool was located downwind of the oxygen injectors. Under this condition, the high airflow and heat drafted the halon away from the base of the fire.

Testing verified that the positioning of the penetrator tool in relation to airflow is important, but the most important objective is to get the tool as close as possible to the base of the fire. Testing showed that for a compartmentalized aircraft like the B-52, the aircraft skin penetrator agent applicator tool can suppress a fire under almost all conditions if firefighters can penetrate the compartment in which the fire is burning.

On the C-131A, fires were conducted in a large cargo hold. With a large volume area (10,000 to 20,000 ft^3), the location of the penetrator is important. Most crash rescue vehicles with Halon 1211 carry enough agent to make the entire volume (up to 21,000 ft^3) of a C-14 or C-17 inert, if necessary. The amount of agent used can be greatly reduced by the placement of the penetrator tool. In the case of forced airflow in a large volume, placement of the penetrator tool is critical. In such a large volume, spraying against the airflow becomes very difficult, if not impossible.

The tests mentioned above showed that one of the major advantages of using the aircraft penetrator tool is its ability to safely apply extinguishing agents to the interior void of an aircraft. This is especially useful if the fire is located in an enclosed void and it is impossible to gain direct access to it. Applying an agent to the interior currently requires opening a window or a door and spraying the agent through that opening. In some cases the fire may have used up all of the oxygen and the heat may have generated combustible gases. As soon as entry is made, fresh air flows in, supplying oxygen to the fuel vapors, which can explode or flash, again starting the fire. If a firefighter is next to the opening, the resulting fireball could cause serious injury. Also, standing outside the aircraft and spraying agent into the interior of the aircraft results in a large amount of air being drafted into the fire. With the penetrator tool the firefighter needs to look for the physical location of the fire and then approach the exterior of the aircraft and penetrate into the airspace next to the fire and suppress it. After starting the agent flow, the firefighter can release the tool, leaving it locked into the airframe, and agent flow can then be safely controlled from the truck. In this way the skin of a burning aircraft can be penetrated and halon applied to suppress the fire, followed by AFFF or water to cool the interior of the aircraft. This will also extinguish a Class A fire and quickly allow safe entry into the aircraft.

5. Use With Alternative Agents

During testing, several alternative agents were dispensed from the penetrator tool and, based on these tests, the following general comments are offered.

- Halon 2402 had a smaller exit angle of about 30 degrees, with a longer effective throw range. The droplets were very small in diameter and did not have a lot of momentum, making them more susceptible to air movements. Where Halon 1211 was not able to penetrate to the base of the fire, Halon 2402 with its greater density was able to suppress the fire.

- AFFF had an exit angle of about 70 degrees with a throw range the same as that of Halon 2402. There was little aeration; therefore, there was little blanketing effect. The film that formed was very thin and easily broken. A detailed discussion of application of AFFF through a penetrator tool is contained in Reference 6.

- Water was about the same as AFFF. The main advantage is the large amount of cooling available.

SECTION III

TRAINING, USE, AND EVALUATION

As part of the present effort, government personnel were asked to evaluate the penetrator tool. Personnel at eight locations were trained in the operation of the penetrator tool and asked to use and evaluate the tool for a 60-day period. The results of the 60-day evaluation period are summarized in Section IV. The evaluations were made by completing a form which was provided to all personnel (Appendix D). The training consisted both of classroom instruction in the operation and maintenance of the tool and field training. Training seminars were held at the following locations:

- Naval Air Station
  Pensacola, Florida
  Contact: Fire Chief S. Booze

- Marine Corps Air Station
  Yuma, Arizona
  Contact: CWO-3 J. Rodriguez

- Naval Air Station, Oceana
  Virginia Beach, Virginia
  Contact: Fire Chief A. Cuthriel

- NALF Fentress Airfield
  Norfolk, Virginia
  Contact: Lt. McFarland

- Naval Air Station
  Cecil Field, Florida
  Contact: Fire Chief J. Moneyhan

- Marine Corps Air Station
  Beaufort, South Carolina
  Contact: WO S. Archer

- Federal Fire Department
  San Diego, California
  Contact: Fire Chief D. Crutchfield

- COMNAVAIRPAC
  San Diego, California
  Contact: Senior Chief R. Billiet

A. CLASSROOM SESSION

The first part of the training seminars consisted of a classroom session. During the first part of the classroom study the history of the penetrator was presented. This gave personnel the background information on why the penetrator tool was needed and how it was developed. It also provided an idea of how quickly the tool went from concept to final production and the amount of effort expended to accomplish this. Next, the penetrator tool was disassembled and each part of the tool was discussed. A detailed description of the function of each part of the tool made it easier to understand the overall function and interaction of every part. This allowed the operating firefighters to determine whether the tool appeared to be operational and to perform needed repair quickly and efficiently. During reassembly of the penetrator tool the maintenance and repair of each part was covered. The need for a strong maintenance program was emphasized, and it was pointed out that a well-structured maintenance program is presented in the operational manual. If this program is followed strictly, the life and operational ability of the penetrator tool will be maximized.

The firefighters were then allowed to gain some hands-on experience with the penetrator tool. Each firefighter disassembled the penetrator tool and checked it for damaged or worn parts, then reassembled it and readied it for operation. Every firefighter was able to accomplish this task without a problem, and the tool was always returned to full operational condition.

Before the firefighters went out into the field to use the penetrator tool, the safety requirements and hazards inherent in the operation of the penetrator tool were covered. It was explained to the firefighters that, as with all equipment, there are hazards unique to the operation of the penetrator tool. Because there are very few moving parts and the construction of the tool is basic and rugged, few hazards needed to be addressed. It was pointed out that the most dangerous part of the penetrator tool is the large, sharp cutting bit. Finally, the clearances and pressures needed to operate the tool were discussed.

B. FIELD TRAINING SESSION

The second part of the training seminar was field training in the use of the penetrator tool. Specific details of the field training session are described below for each training location; however, in general the following points were discussed:

- Review of safety and operational procedures,
- How to approach the plane,
- How to hold the tool during drilling,
- Limitations of the tool,
- Range and mobility for operator and tool, and
- Where to drill when using the penetrator tool.

At the Naval Air Station at Pensacola, Florida an F-3B aircraft was used for field training. There were 28 Navy personnel on location during this portion of the training seminar. The Navy firefighters used the tool to drill holes through the aircraft, using both the self-contained bottle and a constant-pressure system. While using the constant-pressure feed, all of the Navy firefighters were able to drill at least two holes each. The average time to drill a hole was approximately 10 seconds. This time varied, depending on the location of penetration on the airframe and the number of panels at that location. Drilling the tail section was considerably easier than drilling the front section of the aircraft, where armored panels protected the pilot and forward control assemblies. Drilling at these locations took up to 15 seconds.

With the self-contained system charged up to 2000 lb/in^2, the penetrator tool was used on the rear section of the aircraft. The firefighter using the tool was able to penetrate the aircraft five times in an average time of 6 seconds before running out of air. Interest was shown in the ability of the tool to drill through a Plexiglas™ canopy with the self-contained bottle charged to 2000 lb/in^2. With the firefighter on a ladder, the canopy was penetrated in 14 seconds. Although the drilled hole was rough with sections chipping off, this did not interfere with the operation of the skin penetrator. When the session was over, the attending personnel were shown the weaknesses and strengths of the penetrator tool. The firefighters were shown how to approach the aircraft after finding the location of the fire and, upon arriving at the aircraft, which configurations are easier to drill and which to avoid. Another point stressed was the importance of moving the drill if the bit stopped cutting. It was pointed out that valves and steel hangers are located under the skin and no amount of drilling will penetrate them; therefore, continued drilling of these locations is a waste of time and air pressure. Moving the drill as soon as possible will provide an opportunity to penetrate in another location.

At the Marine Corps Air Station at Yuma, Arizona, an F-4 aircraft was used during field training. There were 41 Marine firefighters from three Marine bases and one civilian firefighter from Yuma. The Marine bases repre-sented were Yuma, Camp Pendleton, Tustin, Twenty-Nine Palms, and El Toro Air Stations. During drilling, it quickly became evident that the plane was protected by armored panels and would be difficult to penetrate. Penetration was accomplished using the constant-pressure source; however, penetration required an average time of 30 seconds. Because of the amount of damage to the aircraft, there were very few places to drill while standing on the ground; therefore, for instruction, the firefighters moved to the top of the wing and drilled into the main fuselage. Because the plane was armored, the drilling times were long, the starting tip was torn off the drill bit, and the flow tube was showing excessive wear. One of the self-contained bottles was charged to 2200 lb/in^2 and the tool was used to try to penetrate the canopy on the aircraft. Before the bit was able to cut through the canopy the air source was depleted. Inspection of the canopy showed that the Plexiglas™ was 0.75 inches thick. This was twice as thick as the canopy on the F-3B at Pensacola. It is estimated that to completely drill a section that thick would require twice the air supply.

The tool was moved to the other wing, and the aircraft was prepared for fire testing by placing a 5-gallon can containing 2 gallons of fuel in the empty engine nacelle. A 150-pound portable wheeled unit and a P-19 fire truck provided the Halon 1211 supply to extinguish the fire. The firefighters approached the wing and penetrated the upper section of the fuselage into the engine nacelle, where the fire was extinguished (Figure 7). Penetration required 35 seconds; however, once the penetration

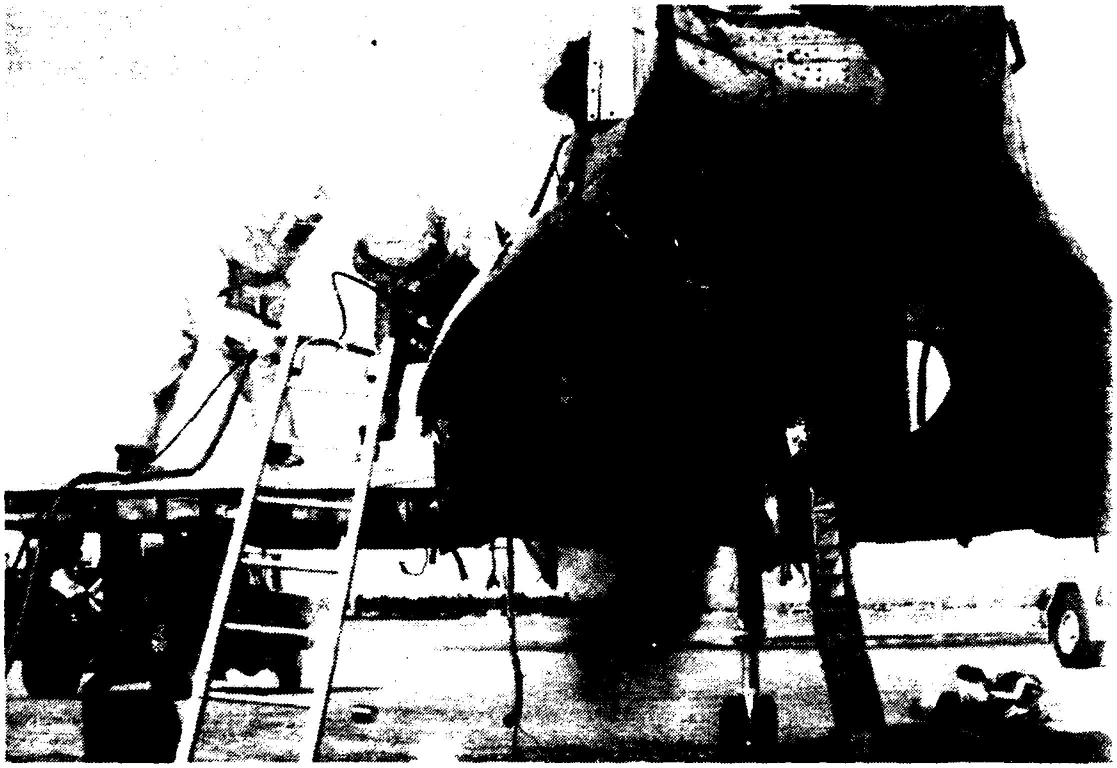

Figure 7. Extinguishment of Engine Nacelle Fire Simulation by Marine Firefighters.

was completed, the fire was quickly extinguished. When the bit was entering the engine nacelle, sparks were obs ved. Inspection showed that the it was cutting through a heat shield to enter the engine nacelle. Overall, the bit had to cut through a 0.068-inch hardened alloyed aluminum plate and a titanium heat shield to enter the engine nacelle.

During the fire tests the tool became lodged inside the aircraft several times and was very difficult to remove; at one point removal required 15 minutes. This occurred because the firefighters were shifting their stance when they penetrated the first skin and started drilling the inner layer, thus, drilling the inner layer at a different angle. This made drilling the inner hole more difficult b ause of the binding on the flow tube by the different ski layers. The skin would then grab the serration as the tool was being removed, as it was designed to do. With the serrations the tool can be removed only at the same angle as the one at which it was drilled; otherwise the tool locks onto the skin to hold itself in place. To remove the tool required tearing the inner skin to relieve the bind on the outer skin, and resulted in damage to the exterior of the flow tube and to the front bushing. Because of the increased effort and damage to the tool, this point should be emphasized and included in the operation manual.

For field training at the Naval Air Station, Oceana, an F-8 fighter jet was used. The penetrator tool was easily able to drill through the skin of this aircraft. A total of 50 holes were drilled during field training.

Because of limited facilities, the training classes at NALF Fentress were conducted at Oceana, which supports Fentress. For field training, two aircraft bodies were used. First was a helicopter which had a thin aluminum skin that was easy to drill through. This allowed the firefighter to drill many holes and become familiar with how the tool works. After drilling through the helicopter skin, the class continued training using an F-4 fighter. Because of the thickness of the skin, most places on the aircraft were hard to drill through. At the front of the aircraft, there were panels which were easier to penetrate, and most of the penetrations were done there.

Two separate classes were conducted at Cecil Field. This permitted both shifts to learn about the use and maintenance of the aircraft penetrator tool. Field testing was done with an A-4 aircraft. While drilling through the skin of the A-4, the firefighters encountered no problems with the penetrator tool.

At the Marine Corps Air Station, Beaufort, South Carolina, two training classes were conducted. The first class was a short, informal class to introduce that shift to the aircraft skin penetrator. A complete, formal class was conducted the next day. A concern of the firefighters was the use of halon, for they believed that minimal exposure to halon was extremely harmful. The classroom session convinced the Marine firefighters of the value and safety of the penetrator tool with halon. Field training was done with the use of an F-4 fighter aircraft. There were some places where the penetrator tool took an extended period of time to drill. By reinforcing the need for training and knowing exactly where to penetrate the aircraft, it was clearly illustrated how a firefighter can easily drill into any aircraft and extinguish internal fires.

In San Diego, California, the Federal Fire Department, which controls all of the local airfields, and the ship boatswains from COMNAVAIR-PAC, who control all aircraft-carrier fire situations, were given training classes. For both groups, field training was accomplished using an F-4 fighter aircraft. By inspecting the aircraft first, the firefighters were able to find areas which allow relatively easy penetration of the aircraft skin. With the use of adapters, a 1 1/2-inch water hose was used to illustrate the spray pattern of the penetrator tool.

SECTION IV
PENETRATOR TOOL 60-DAY EVALUATION

A. INTRODUCTION

The skin penetrator tool was evaluated at eight locations by the firefighters at those locations. Before conducting the evaluation, each firefighter received an 8-hour course on the use and maintenance of the tool. This course was equally divided between classroom training and field training. The skin penetrator tool was then put into service at those locations for a period of 60 days prior to this evaluation.

The areas evaluated ranged from how the skin penetrator functioned to the type of training the firefighters received in the use of the tool. The evaluation questionnaire is contained in Appendix D, and the quoted responses from the evaluation are in Appendix E. Comments on the skin penetrator's performance ranged from detailed suggestions to "yes" or "no" responses. However, it was generally thought that the skin penetrator was too heavy, the barrel was too long for fighter aircraft, and the tool did not have a large enough self-contained air supply to operate the pneumatic drill. Additionally, the skin penetrator was very slow at drilling through nonaluminum surfaces and stalled under a variety of circumstances. The skin penetrator was also difficult to store aboard the CFR vehicles used in the evaluation.

The consensus of this evaluation was that the tool could be improved by removing the portable high-pressure bottle and replacing it with a large high-pressure air cylinder aboard the CFR vehicle or on a backpack. This would make the tool considerably lighter and easier to store, and would increase the number of holes that could be drilled in an aircraft. Further recommendations based on the total evaluation are contained in Section V.

B. QUESTIONNAIRE SUMMARY

Below is a summary of the responses from the 60-day evaluation of the skin penetrator tool.

1. HIGH PRESSURE CYLINDERS

a. What problems did you have with the high-pressure cylinders?

- The bottle did not have a sufficient quantity of air.

b. Were any leaks detected in the cylinders? If so, where were they and what was done to stop them?

- No leaks were detected.

c. Did the cylinders charge properly? If not, what was the difficulty and solution?

- No difficulties were encountered.

d. Other problems or recommendations; be specific.

- The tool is easier to handle and more reliable if an external air supply is used to power the drill.

2. REGULATOR

a. Were any leaks detected in the regulator? If so, where were they and what was done to stop them?

- No leaks were detected; however, on several occasions, the manual release for the relief valve was accidentally tripped. It is recommended that a screw-out or pitcock type manual release be used instead of a needle valve.

b. Was any damage to the sealing surfaces noticed? If so, what type of damage was it and under what circumstances did it occur?

- No damage was noticed.

c. Did the regulator remain where it had been set? If not, why not and what was done to correct the problem?

- There were no problems with keeping the regulator set.

d. Other problems or recommendations; be specific.

- It was recommended that some type of marking system be used to ensure the proper setting of the regulator pressure.

3. DRILL

a. Were any leaks detected in the oil? If so, where were they and what was done to stop them?

- No leaks were detected.

b. What difficulties were present during filling of the oiler?

- None.

c. If the drill stalled during use, under what conditions did this occur? What changes were made to avoid a repetition of this occurrence?

The drill was found to stall in the following circumstances:

- If the course followed by the drill was not maintained in a straight path.
- If the drill bit hit a solid object behind the skin of the aircraft.
- If the aircraft skin was nonaluminum.
- If the penetrator motor slowed because of low air pressure.
- If too much pressure was used to force the bit through the skin of the aircraft.

d. Was any movement between the holder and tool body noticed? If so, how severe was it and under what conditions did it occur?

- No movement was noticed.

e. Other problems or recommendations; be specific.

- The drill should turn at a higher speed.
- The unit should be shorter.
- The oiler may be too delicate for an aircraft carrier environment.

4. DRILL BIT

a. In what circumstances did dulling or breaking of the cutting edge occur?

- The bit dulled when holes in nonaluminum surfaces were attempted, such as in aircraft ribs, engine compartments and reinforcement panels.
- The bit chipped when it was dropped.

- The cutting edge of the bit collected metal buildup from previous drilling.

b. Did the bushing show excessive wear: If so, under what conditions did this occur?

- No excessive wear was noticed.

c. Did the clip hold the bushing properly? If not, under what conditions did it fail?

- Failure of the clip occurred only when the penetrator was improperly forced through the skin of an aircraft. The clip was easily replaced.

d. What difficulties were present when setting the bushing to bit clearance? What adjustments were made?

- A cover for the cutting tip was recommended for safety reasons.

e. Other problems or recommendations; be specific.

- It is recommended that a plastic pipe be included as part of the tool to protect the drill bit and shaft.

5. TOOL BODY

a. Was there damage to the penetrator tip? If so, how did it occur?

- Normal wear of the tip occurred.
- The tip came off when the tool was used improperly.

b. Were any leaks detected in the seals within the tool body? If so, where did they occur and what was done to stop them?

- No leaks were noticed.

c. Did the valve controlling the agent work properly? If not, under what conditions did it fail and what was the nature of the failure?

- The valve worked properly.

d. Was there any damage to the handlines? If so, what caused the damage?

- No damage to the handlines was noticed.

e. How did the location of the handles aid or hinder maneuvering the tool?

- Handles are in a good location.
- The pistol grip should be reinforced because it was often used to remove the tool.
- The handles should be smaller so that the tool can be stored in a smaller space.

f. Other problems or recommendations; be specific.

- The agent quick-connect of the SPAAT should be compatible with the female threads of the Halon 1211 booster line. The present booster lines cannot be used.
- Installation of an additional handle at the pistol grip position may be helpful during removal of the tool.
- The large handles on the tool make it hard to store on CFR vehicles.

6. TRAINING

a. What training did you receive on the use of the penetrator tool?

- Four hours of classroom training and 4 hours of field training.

b. When training was completed, were you confident of your ability to use the tool?

- Personnel understood how to use the tool.
- Confidence in the tool could be increased by increasing drill speed and available air supply.
- Personnel did not have enough experience with the tool to be confident of the tool's capabilities.

c. What areas require specialized or more detained training?

- How to repair and sharpen drill bits.
- Detailed knowledge on how to repair the regulator and in-line lubricator.

d. Did the weight of the tool cause problems during training? If so, what were the problems and were they overcome after you became familiar with the tool?

- The penetrator tool was hard for smaller firefighters to use.
- The penetrator tool was very difficult to use at any level above the chest.
- The barrel of the penetrator tool should be shorter.

e. How was the tool attached to the fire truck? Was it secure? Was it convenient?

- Not attached to truck.
- Attached to P-19. Not secure or convenient.
- Carried in a separate box.

f. Other problems or recommendations; be specific.

- Train on a number of different types of aircraft.
- Training should include how to sharpen bits.
- Training should be more realistic.

7. SAFETY

a. - What standard safety precautions were used when operating the penetrator tool? Were they adequate?

- Full turn-out gear.

b. Were there any accidents or major damage sustained while using the tool? If so, describe the event in detail.

- None.

c. What additional safety precautions were taken? Were they effective?

- Work as a team.
- Charge 1-1/2-inch hose line during live fire drills.

d. What new areas of concern for safety were discovered while using the tool?

- Caution should be used to avoid drilling into high voltage wiring, LOX, fuel tanks, or hydraulic components.

- When halon is injected into the aircraft where crew and passengers are located, the halon may cause a serious respiratory problem for the occupants.

- A cover for the drill bit should be included.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Based on testing and evaluation of the penetrator tool the following conlusions were reached.

1. Fire testing showed that the penetrator tool was of great value in extinguishing interior aircraft fires, and in some cases it was essential.

2. By penetrating the aircraft and applying agent directly to the fire, the penetrator tool allows increased effective use of agent.

3. Use of the penetrator tool reduces the hazards to which a firefighter is exposed. When approaching the exterior skin of the aircraft there is a barrier between the fire and the firefighter and direct exposure to the fire is minimized.

4. After penetration and initiation of discharge, the tool can be left in place and the firefighter is free to accomplish another task or remove himself to safety.

5. If it has a drill-type cutting bit, the tool can drill multiple holes and penetrate several layers of different types of materials.

6. A large amount of human strength is not needed to operate the tool because of the pneumatic power source driving the cutting bit.

B. RECOMMENDATIONS

Several recommendations are made to improve the design of the tool for easier and more efficient operation. In addition, recommendations are included, emphasizing requirements for training.

1. A different air motor is needed which is more efficient and will produce more torque. This will decrease the drilling time and reduce the stalling and binding, especially when penetrating high-tensile-strength materials. Currently there are motors on the market which will satisfy all of these requirements with only a small increase in the overall tool cost.

2. The starting tip on the drill bit should be redesigned to allow for the higher stresses encountered with high-strength materials without yielding and failing. The present starting tip is usually torn off the end of the bit, resulting in longer cutting times. The redesigned tip would reduce drilling times which appear to be dependent on the ability of the starting tip to cut the initial hole.

3. Much of the testing was conducted with a small air bottle attached to the drill. An external nitrogen bottle should be used to power the drill. The most recent update to the AMETEK operations and maintenance manual calls for the small attached bottle be used only as a 30-second backup with a large external nitrogen bottle used as the main drive for the drill.

The following recommendation is emphasized. It pertains to training operations but is imperative for the safe, efficient, and effective use of the penetrator tool.

4. Since this is a new piece of equipment, it will require comprehensive training and time to integrate it into the system. The firefighters need to feel comfortable with and knowledgeable about the tool before they are willing to use it routinely.

It is recommended that centralized training sessions be conducted for firefighter training officers, allowing enough classroom and field training for the officers to be competent in the operation and maintenance of the penetrator tool. The training officers would then be better able to train their troops in the effective use of the penetrator tool. This would result in increased acceptance of the tool and would more efficiently integrate the tool into military firefighting operations.

REFERENCES

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APPENDIX A

AIRCRAFT PENETRATOR TOOL

TEST PLAN

SECTION I--INTRODUCTION

1.1 Objective. To demonstrate the operation of the Skin Penetrator/ Agent Applicator Tool (SPAAT) to U.S. Navy firefighting personnel for the purpose of putting out internal aircraft fires. Also to allow US Navy firefighting personnel to have hands-on operation experience.

1.2 Background. The Air Force Engineering and Services Center (AFESC) contracted Ametek, Inc./Offshore Research and Engineering Division (ORED) in 1982 to design, build and test a tool for the penetration of aircraft skin and application of fire-extinguishing agent.

The need for development of the tool evolved from the fact that current military firefighting equipment does not provide rapid access to aircraft fires occurring in airframe voids where access ports are either limited or not provided. Various aircraft sizes, configurations, and the use of high-strength metal alloys make forced entry to these areas time-consuming and difficult. To correct this deficiency, a lightweight, hand-held, self-powered device was needed, which would penetrate aircraft skin and serve as a discharge outlet to dispense fire-extinguishing agent.

Ametek, Inc./ORED designed a tool to meet the requirements identified by the Air Force and submitted ORED Report No. 14.46 defining the design in February 1983. This report describes the tests conducted to qualify the Ametek design to the requirements of the contract.

1.3 USAF/US Navy Requirements. The USAF and US Navy identified requirements for the Aircraft Skin Penetrator/Agent Applicator are as follows:

1.3.1. Penetration Requirements

The tool shall penetrate aircraft skin materials and any internal thermal or acoustical insulation materials and cabin panels. The penetrator device shall be capable of penetrating a minimum of 14 inches.

1.3.2. Mechanical Actuation

The tool shall be mechanically actuated and safe to operate in any explosive or flammable environment. The device shall not incorporate ballistic or explosive propellant materials.

1.3.3. Operation by One Person

The tool shall be operated by one person from a variety of positions, from hip level to overhead at arm's length from various footings, including the ground, aircraft surfaces, and a ladder.

1.3.4. Halon 1211 Delivery

The tool shall be suitable for delivery of Halon 1211 fire-suppression agent.

1.3.5. Firefighting vehicle Base

The tool shall be designed to be fully functional from a firefighting vehicle as the operational base.

1.3.6. Quick-Disconnect

The tool shall have quick-disconnect capability for both input connection and nozzle output connection.

1.3.7. Halon 1211 Discharge Rate

The tool shall be capable of discharging Halon 1211 at 5.0 to 5.5 pounds/second.

1.3.8. Throw Range

The tool shall be designed to have effective agent throw range of not less than 30 feet.

1.3.9. "Trigger" Type of Turn-on

The tool shall have "trigger" type of actuation turn-on.

1.3.10. Retention

The tool shall have a suitable retention means to prevent the penetrator from falling out during use if unattended. (Note: mechanical or non-mechanical means are acceptable.)

1.3.11. "Human Engineered"

The tool shall be "human-engineered" for operational use by a single firefighter wearing full protective proximity clothing, including gloves, as required for a realistic fire environment.

1.4 Scope. The scope of this task shall include the acquisition and operational testing and evaluation of the newly developed aircraft skin penetrator/agent applicator and making modifications to the penetrator as necessary for Naval fleet use. Government personnel will be trained and will operate the penetrators during the evaluation period.

SECTION II--DESCRIPTION OF TESTS

2.1 Test Article. The Ametek tool was designed to penetrate aircraft skins and to permit rapid turn-on of agent within confined spaces of aircraft.

2.1.2. Skin Penetrator/Agent Applicator Description

The Skin Penetrator/Agent Applicator employs a small precharged pneumatic cylinder (21 ft^3 at 3000 lb/in^2, DOT 1A approved) for energy storage, a standard commercially available pneumatic drill for energy transfer, and a small compact human-engineered assembly package of all the components.

The energy storage is sufficient to penetrate 3-4 holes in the heaviest wall aircraft airframe constructed.

A small air pressure gauge is provided to verify the fully charged readiness of the tool.

Charging the compressed air storage bottle may be accomplished by using standard breathing bottle equipment presently in place at most firefighting facilities.

A quick-connect/disconnect fitting is provided for the agent supply line with a standard firefighting type of quarter-turn ball shutoff valve.

The compressed air storage bottle is secured with quick-acting over-center toggle clamps for ease of assembly and periodic interchange of bottles, if desired.

The bottle is charged for 3000 lb/in^2g on the compressed air facilities used for breathing bottle charging. A regulator controls pressure to the energy transfer system at 105 lb/in^2g with flow initiated by an index finger-actuated trigger.

2.1.3. Systems and Subsystems Organization

The Skin Penetrator/Agent Applicator System is organized into the following systems and subsystems:

System/Subsystem Number	Title
1.0	Complete Tool Assembly
2.0	Penetrator
2.1	Tool bit
2.2	Drive
2.3	Energy Storage
2.4	Energy Release
2.5	Assembly Clamps
2.6	Energy Connection
3.0	Agent Transfer
3.1	Agent Connection
3.2	Shut-Off/On Valve
3.3	Conduit
3.4	Discharge Nozzle
4.0	Tool Retention
4.1	Retention Features

2.2 Testing Facilities. The aircraft skin penetrator/applicator tool will be initially tested at Kirtland Air Force Base using the following facilities:

- Civil Engineering Research Facility testing area
- B-52 body located on McCormick Test Ranch
- C-131 airframe located at base fire training area

After the initial evaluation is completed, a series of training sessions will be conducted at military bases. These sessions will include both classroom instruction and field training.

2.3 Photography. Each test set-up will be photographed for complete documentation. In addition, large fire tests will be covered with normal-speed VCR recordings.

2.4 Test Preparation. A 60-day testing program will be performed on the penetrator tool looking at tool performance, tool maintainability, and human engineering of the penetrator tool. The penetrator tool will be run through a series of extensive evaluation tests over the period.

After modifications and operational concept have been incorporated into the tool design a series of training sessions will be conducted around the country. These training sessions will be conducted to teach firefighters the proper technique in operating the skin penetrator tool. The firefighters will then operate and use the penetrator tool over a period of 60 days. At the conclusion of this period, a questionnaire will be filled out and returned for analysis.

2.5 Testing. The following testing will be conducted at Kirtland AFB.

2.5.1. Initial Review

The tool will be examined when it is received. It will be checked for:

- Damage during shipping.
- Clarity and completeness of operation manual.
- Problems during tool construction.
- Problems during tool breakdown.
- Repairability of tool during use.

2.5.2. Mechanical Testing.

A. Onboard air supply

This testing will focus on the performance of the tool during use.

(1) How many holes it will drill
(2) Maximum material thickness which can be drilled
(3) How loading affects drilling time

B. Length of bit life
C. How bit life varies with types of materials
D. How will drilling time vary as the bit degrades
E. Life of drill motor

(1) Under different types of use
(2) With different supply pressures

During all of the above testing the following information will be obtained:

A. Type of material
B. Thickness of material
C. Supply pressure
D. Time to complete drilling operations
E. Number of times each bit has been used
F. Number of times drill motor has been used
G. Number of holes drilled with onboard supply

Other information to be obtained:

A. Revolutions per minute at different supply pressures
B. Change in revolutions per minute over time
C. Change in drilling times over time

2.5.3. Personnel Testing

This section will examine how the firefighter and tool work together.

A. Ease of use of the tool
B. Restrictions when using the tool

(1) Weight of tool
(2) Physical size of tool
(3) When tool is used in conjunction with other firefighting gear

During the above testing the following information will be gathered:

A. Video tape recordings of tests
B. Personal comments by technicians before and after tests

2.5.4. Fire Testing

This section will examine how the total system performs.

A. Flow rate of halon through nozzle
B. Throw range of halon
C. Firefighting capability of tool

(1) On an airframe
(2) On a pool fire

Data to be gathered during above testing

A. Video tape recordings of tests
B. Amount of fuel burned
C. Quantity of agent used
D. Time required for extinguishment
E. Placement of tool

2.5.5 Field Training Tests. During the field training sessions the test outlined below will be accomplished. These tests will be run to show the firefighters the basic operation of the skin penetrator tool. After the initial tests each firefighter will receive hands-on training with the penetrator tool.

NO. OF REQUIRED TESTS	TEST SEQUENCE	DATA OBTAINED BY	GENERAL NOTES
1	Penetrate the skin of the aircraft section in the middle of a panel	Observation	Demonstrates basic tool ability to penetrate the skin of the aircraft
1	Penetrate the skin of the aircraft section approximately 1 inch from edge of rib or longeron	Observation	Demonstrates basic tool ability to penetrate the skin of the aircraft
1	Penetrate the skin of aircraft at least at a 30-degree angle next to a rib or longeron and then penetrate the rib or longeron	Observation	Demonstrates that this type of drilling operation should not be attempted
1	Penetrate the skin of the aircraft on top of a rib or longeron	Observation	Demonstrates that this type of drilling operation should not be attempted

SECTION III--RESPONSIBILITIES

The overall responsibility for the entire test program tests with the Test Director. In addition, he will be responsible for performances of these test event's countdown coordination and procedures, and any extraordinary safety and security precautions during test days. The Test Director will delegate his authority as necessary. Specific responsibilities relative to safety are contained in the appendices.

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APPENDIX B

TEST RESULTS

<u>Test 1</u>

The purpose of this test was to determine the time required for drill bit replacement. The drill bit could not be replaced because of a snap ring. The snap ring is used to secure the drill bit to the front bushing. Replacement required a specialized tool. This is a tool which would not be available in the field for emergency repair.

<u>Test 2</u>

This test was to ascertain regulator output pressure at different bottle pressures, and verify constant pressure head to the drill motor. Results were as follows:

Tank pressure, lb/in^2	Regulator pressure, lb/in^2
2010	100
1800	100
1500	100
1000	100
500	100
250	100

The regulator performed well with no fluctuation in output pressure.

<u>Test 3</u>

This test was to determine how quickly the drill motor will empty the self-contained pressure bottle with the drill motor operating at full speed. Initial pressure was 2200 lb/in^2 feed pressure, 100 lb/in^2 static. Initial running pressure was 80 lb/in^2. At 25 seconds the pressure started dropping. At 30 seconds the running pressure had dropped to 40 lb/in^2, and the motor stopped turning at 38.5 seconds. With drill motors the maximum airflow occurs under no-load conditions, so this was the shortest operating time expected.

Test 4

This test was to determine how quickly the drill motor will empty the self-contained pressure bottle with the motor running at half speed. Initial pressure was 2200 lb/in^2; feed pressure was 100 lb/in^2 static. Initial running pressure was 85 lb/in^2. At 32 seconds the running pressure started dropping. At 40 seconds the pressure dropped to 40 lb/in^2. This was a no-load condition. Maximum airflow used 40 lb/in^2 as cutoff condition; below this pressure the drill would not have the energy to cut anything.

Test 5

This test was to evaluate human/tool interaction with operator wearing full firefighting gear. The test tool was received and modified to use pressure off the fire truck so that the pressure bottle could be removed and the tool reconfigured. With the self-contained pressure bottle the tool has the following dimensions:

Length: 38 inches
Depth: 21 inches
Weight: 24.5 pounds (dry)

Without the self-contained bottle the tool has the following dimensions:

Height: 38 inches
Depth: 12 inches
Weight: 11.3 pounds (dry)

Being less than half the weight without the bottle, the penetrator tool is much more maneuverable in this configuration. With the reduced size, the tool was able to fit in confined spaces to drill through less accessible panels. This also gave the firefighter a large source of pressure, resulting in greatly decreased drilling time.

Overall the penetrator tool is much easier to handle without the self-contained pressure bottle. The overall performance was also increased. If equipment and manpower allows for this modification it should be performed before the tool is used in the field. This modification is explained in the operation manual. All further testing will be done with the tool in the same configuration as it was shipped.

Test 6

This test was to record the rotational speed of the drill motor at different feed pressures. The results are presented in Table B1. The overall efficiency of the drill motor is not very high. With a drill motor the efficiency is higher under full speed and the lowest pressure allowed. Reducing the feed pressure reduces the output torque to the drill bit.

Test 7

This test was to find the time required and the number of holes that can be drilled in a piece of 2024 aluminum using the self-contained bottle charged to 2200 lb/in^2. Feed pressure was 100 lb/in^2 static. The results were

1st	9.3 seconds
2nd	8.2 seconds
3rd	10.5 seconds
4th	40-percent completion.

This was the start of a series of tests to examine the wear on the drill bit as it is being used.

TABLE B1. INITIAL MOTOR TEST.

Full Speed

Regulator Pressure	Rotation Speed, rpm	Percent Change From Previous
130 lb/in^2 static	400	
100 lb/in^2 running	410	Average 403
	400	
	390	Average 390
117 lb/in^2 static	390	Change 3.2
90 lb/in^2 static	390	
	370	Average 370
105 static		Change 5.1
80 running	370	

Half Speed

Regulator Pressure	Rotation Speed, rpm	Percent Change From Previous
	310	
130 lb/in^2 static	300	Average 305
120 lb/in^2 running	305	
	270	
117 lb/in^2 static	280	Average 277
105 lb/in^2 running	280	Change 9.2
	200	
105 lb/in^2 static	265	Average 265
96 lb/in^2 running	270	Change 4.3

Test 8

This test was a continuation of testing to find the time required and the number of holes that can be drilled in a piece of 2024 aluminum using the self-contained bottle charged to 2200 lb/in^2. Feed pressure was 100 lb/in^2 static. Results were

1st	10 seconds
2nd	10 seconds
3rd	11.5 seconds
4th	7 seconds, 70-percent completion

This test was penetration numbers 24, 25, 26, and 27 on the same drill bit.

Test 9

This test was a continuation of testing to find the time required and the number of holes that can be drilled in a piece of 2024 aluminum using the self-contained bottle charged to 2200 lb/in^2. Feed pressure was 100 lb/in^2 static. Results were

1st	11 seconds
2nd	12 seconds
3rd	12 seconds, 90-percent completion

This was penetration numbers 35, 36, and 37 on the same drill bit.

Test 10

This test was a continuation of testing to find the time required and the number of holes that can be drilled in a piece of 2024 aluminum using the self-contained bottle charged to 2200 lb/in^2. Feed pressure was 100 lb/in^2 static. Results were

1st	12 seconds
2nd	12.6 seconds
3rd	15 seconds, 20-percent completion

This was the completion of the drill bit testing. The wear on the bit can be seen after drilling 75 holes. Penetrations went from 3 holes per bottle to 2 holes. Drilling times increased 12.3 seconds from 9.3 seconds. Even with the reductions in penetrations and an increased drilling time the bit was still able to penetrate the aluminum panel. This showed that even after extensive use the bit is still usable.

Test 12

This test was to find the times required and the number of holes that can be drilled in an aluminum panel 0.003 inches thick. Panel stock numbers were:

1560-00-627-0781FG

5-46496-105

F34601-76-A-0720-0204-01

The self-contained bottle charged to 2000 lb/in^2 was used. Results were

1st 10.6 seconds

2nd 26.1 seconds, 90-percent completion

After the completion of the first hole, the drill bit showed damage to the starting tip. On the second hole the bit would not start cutting and needed to be pushed hard to initiate cutting. Taking into account the thickness of the material a penetration time of 10.6 seconds is a low penetration time. After 26 seconds of drilling, the drill's air bottle ran out of air just before penetration was completed. Inspection of the drill bit revealed that the drill bit tip had been damaged. This made starting the second hole very difficult. This may have occurred because the panel was constructed out of high tensile strength aluminum alloy. This resulted in high stresses at the starting tip, which may have caused it to fracture and fail.

NMERI was informed by Ametek that the drill bit was constructed of heat-treated cobalt tool steel.

Test 13

This test was to record the number of holes that can be drilled in an aluminum panel 0.003 inch thick. The result was one hole in 18.6 seconds, using constant-pressure feed. Feed pressure was 105 lb/in^2.

While drilling, the bit was rocked back and forth to help gain initial hole.

Test 14

This test was to record the number of holes that can be drilled in an aluminum panel 0.003 inch thick and the time required using constant-pressure feed. Feed pressure was 105 lb/in^2. The results were

1st	10.97 seconds
2nd	10.07 seconds
3rd	13.37 seconds

It was noticed that the starting tip had fractured pieces of metal off the tip and had made a sharp fractured edge where the starting tip had been. This, along with the rocking, lowered the drilling time. Drilling times appear to be very dependent on the cutting ability of the starting tip.

Test 15

This test was to record the time required to drill through an aluminum panel. Panel assembly numbers were:

1560-508-8234FG

F34601-73-00851

This panel was an aluminum sandwich with a 0.001 aluminum foil honeycombed center covered with a 0.0024-inch aluminum sheet. Constant-pressure feed set at 105 lb/in^2 was used. The results were

1st	1.87 seconds
2nd	1.75 seconds
3rd	1.97 seconds

The panel was very soft aluminum.

Test 16

This test was designed to find the times required to drill the front section of a B-52 aircraft with an aluminum skin thickness of 0.045 inch using a new drill bit. A self-contained bottle charged to 2000 lb/in^2 was used; feed pressure was 100 lb/in^2. The results were

1st	9.2 seconds
2nd	15.0 seconds, stopped
3rd	9.0 seconds

These times are consistent with that of a new bit. On the second hole the bit drilled into a steel electrical wire hanger and the hole could not be completed.

Test 17

The test was to find the time to penetrate the front section of a B-52 aircraft using a self-contained bottle charged to 2200 lb/in^2. Feed pressure was 100 lb/in^2 static. During this test the tool was rammed into the skin with the bit turning. The results were

1st	2 seconds
2nd	10 seconds
3rd	1.2 seconds
4th	1.6 seconds
5th	6 seconds, cut through two walls of fiberglass tubing
6th	2.7 seconds
7th	1.1 seconds
8th	6.4 seconds
9th	No drilling, just rammed through skin

Even though the drilling times were low, this method works only in an emergency situation. After penetration the skin is torn so badly that the tool will not hold itself in position. After ramming the penetrator tool through the skin, the operator needs to hold the tool in position. Some of the tears were 2 inches long.

Test 18

This test was to determine the drilling times and number of holes which can be drilled into the front section of a B-52. The self-contained bottle charged to 2100 lb/in^2 was used. Feed pressure was 100 lb/in^2 static. The results were

1st	10.2 seconds
2nd	10 seconds
3rd	12.4 seconds
4th	5.6 seconds, 70-percent completion

After ramming the aircraft section no noticeable increase in drilling time was observed. While removing the bit, the tool operator encountered problems in that the skin of the aircraft became lodged between the front of the bushing and the back of the drill bit.

Test 19

This test was designed to find the time required to drill through different sections of a B-52 aircraft using a constant-pressure system. Feed pressure was set at 105 lb/in^2 static. The results were

1st	13.1 seconds--1 layer of skin
2nd	10.2 seconds--1 layer of skin
3rd	10.0 seconds--1 layer of skin
4th	11.7 seconds--1 layer of skin
5th	10.3 seconds--1 layer of skin
6th	18.0 seconds--2 layers of skin
7th	11.8 seconds--2 layers of skin
8th	11.1 seconds--1 layer of skin
9th	10.3 seconds--1 layer of skin
10th	18.0 seconds--2 layers of skin
11th	124.0 seconds--2 layers of skin and spine of a support rib

Placement of the drill bit is important as shown in the final hole drilled. No other problems were encountered on any of the other holes.

Test 20

This test was designed to find the time required to drill a hole through a B-52 section, with the tool operator standing on the ground with the penetrator held overhead and with arms fully extended. The self-contained bottle with halon hose connected was used. Initial pressure was 2100 lb/in^2; feed pressure was 100 lb/in^2 static. The result was 29.1 seconds. In this position the amount of pushing force available to drill through the aircraft skin is greatly reduced by the way the firefighter had to stand. Obtaining penetration using a ladder, even with assistance, would not be feasible.

Test 21

This test was to find time required to drill a hole through a B-52 section with the regulator feed pressure at 40 lb/in^2. Initial self-contained bottle pressure was 200 lb/in^2. The result was 15.1 seconds for 20 percent penetration. At the lower regulator pressure the drill turned very slowly and could not produce much torque to cut the aluminum skin.

Test 22

This test was to find the time required to drill a hole through a plate of 6061-T6 aluminum 0.128 inch thick. A constant-pressure system was used; feed pressure was 105 lb/in^2 static. The result was 39.7 seconds. Until the starting tip had cut the initial hole, drilling required a large amount of physical pressure. Once through the skin, the drill bit had a tendency to overfeed and stall the motor.

Test 23

The purpose of this test was to find time required to drill a hole through a plate of 6061-T6 aluminum 0.125 inch thick. A constant-pressure system was used; feed pressure was 105 lb/in^2 static. The result was 32 seconds. Until the starting tip had cut the initial hole, drilling required a large amount of physical pressure. Once through the skin, the drill bit had tendency to overfeed and stall the motor.

Test 24

This test was to find the time required to drill a hole through a plate of 6061-T6 aluminum 0.245 inch thick. A constant-pressure system was used; feed pressure was 105 lb/in^2 static. The result was 32 seconds. After the initial hole was cut the bit had tendency to overfeed and stall the motor. To continue drilling, the bit had to be pulled out of the hole and slowly reentered, allowing the bit to cut off the burr which had stopped the motor.

Test 25

This test was to find the time required to drill a hole through an aluminum loading ramp 0.38 inch thick. A constant-pressure system was used; feed pressure was 105 lb/in^2 static. The result was 60 seconds. The aluminum in the loading ramp had a lower tensile strength and hardness than the 6061-T6 aluminum. The drill motor stalled less frequently.

Test 26

This test was to find the time required to drill a hole through a plate of 6061-T6 aluminum 0.628 inch thick. A constant-pressure system was used; feed pressure was 105 lb/in^2 static. The result was 165 seconds. Problems with stalling were more pronounced as the thickness of the material increased.

Test 27

The purpose of this test was to find the time required to drill a hole through a plate of 6061-T6 aluminum 1.05 inches thick. A constant-pressure system was used; feed pressure was 105 lb/in^2 static. The result was 59 seconds. The large pressure bottle supplying the constant-pressure had to be changed. This caused the head pressure to drop during part of the drilling operations, increasing the drilling time.

Test 28

This test was designed to find the time required to drill a hole through a 55-gallon steel drum, using a constant-pressure system. Feed pressure was 105 lb/in^2 static. The result was 90.3 seconds. Problems occurred with stalling and cutting off the resulting burr.

Test 30

This test was to find the time required to drill a hole through a plate of 1020 mild steel 0.184 inch thick, using constant-pressure system. Feed pressure was 105 lb/in^2 static. The result was 368.6 seconds, 95-percent penetration. A reduction in feed pressure occurred on the last part of the test. There was also a continual problem with the drill motor stalling.

Test 31

Final drill motor tests were using a constant-pressure system with motor running at full and half speed. Feed pressure varied from 140 lb/in^2 static to 105 lb/in^2 static. The results are presented in Table B2. The tool showed more degradation at higher pressure, presumably because of worn seals.

Test 32

This test was to find the time required to drill a hole through a section of an A-4 aircraft, using a constant-pressure system. Feed pressure was 105 lb/in^2 static. The result was 13 seconds. The hole was drilled in the upper part of the engine compartment from on top of the wind.

Test 33

This test was to find time required to drill a hole through an HC-131A aircraft. Drilling was done on a ladder using a constant-pressure system. Feed pressure was 105 lb/in^2. The result was 15 seconds. The aluminum on the HC-131A was 0.056 inch thick. This thickness and the necessity of working on a ladder resulted in longer drilling times.

TABLE B2. FINAL MOTOR TEST

Full Speed

Regulator Pressure, lb/in^2	Rotation Speed, rpm	Percent Change and Average
130 static	385	
	390	
100 running	390	Average 388
117	380	Average 378
	375	
90	380	Change 4.0
105	365	Average 363
	365	
80	360	Change 4.0
	Half Speed	
130	285	Average 290
	295	
120	290	
117	275	Average 273
	270	
105	275	Change 5.9
105	260	Average 262
96	265	Change 4.0

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APPENDIX C

SAFETY PLAN

1.0 PURPOSE. This safety plan establishes the safety areas for the testing site and all related functions thereto, to be conducted at Kirtland Air Force Base, New Mexico, and identifies the agency responsible for each of these areas. All references to the test throughout this safety plan will pertain to the tests to be conducted at Kirtland Air Force Base, New Mexico. The detailed safety rules which are applicable to this project are documented herein. Before any fire testing can be conducted at Kirtland AFB, New Mexico, the Base Fire Chief must be notified. The following safety documents are applicable to this test:

AFOSH Standards
AFR 127-4

2.0 OVERALL SAFETY RESPONSIBILITY. NMERI, as Test Director, is responsible for enforcing the overall safety program for the test. The Base Fire Chief or his designated representative will act as the safety officer during all actual fire tests. The Test Director is the safety officer for all other events at the test site. The Test Directo will maintain close coordination with the NMERI Safety Officer on all safety matters.

3.0 SAFETY AREAS. The safety requirements of the test have been divided into three separate and distinct areas to facilitate the establishment of specific requirements for the diff ent areas of operation. The safety requirements are divided into three areas as follows:

a. General Safety
b. Construction Safety
c. Fire Safety

4.0 GENERAL SAFETY. The responsibility for general site safety resides with NMERI. The authority to execute specific safety directives is delegated to the Test Director. NMERI is responsible for notification and publicizing the test (when applicable).

a. Safety Briefing. The Test Director will brief all NMERI personnel and/or supervisors of construction crews on the safety hazards existing within the test site. Supervisors will, in turn, brief their personnel on these hazards.

b. Visitors. Visitors shall not be allowed at the test site without approval of the Test Director or his authorized delegate. Visitors shall be instructed on applicable safety regulations.

c. Individual Safety Responsibility. Careful attention to the potential hazards involved in work dealing with fire must be stressed at all levels of responsibility. The purpose of the safety rules outlined herein is to present the most important elements in setting controlled fires.

These rules do not cover all the possible hazards or safety precautions necessary at the site.

As new problems arise, new safety measures will be established to cope with them. In the interim, common sense must be applied to ensure that safety prevails. This entire Safety Plan must be closely followed by all personnel and enforced by all supervisors. The procedures contained herein shall be accepted as minimum standards until such time as the Test Director, with the concurrence of the NMERI Safety Officer, authorizes deviation therefrom.

d. Vehicles. Speeds shall not exceed 20 mph when driving on unpaved roads. Seat belts will be used at all times while vehicles are in motion. When a vehicle is parked, the hand brake will be set and the transmission put in park or reverse.

e. Accident Reporting (Emergency).

(1) Scope. This standard procedure is intended as a guide to ensure expedient handling and care of personnel injured in an accident or disaster. All "post-emergency" reporting and investigation of an accident will be performed in accordance with applicable Air Force regulations and is not considered to within the scope of this standard procedure.

(2) Responsibility. Every person involved in this program must be completely familiar with the emergency reporting procedures established by this plan and must implement these procedures immediately in the event of an accident. The Test Director must familiarize all supervisors with this standard procedure. The supervisor must familiarize subordinate personnel with the procedures established by this plan.

(3) Emergency Reporting Procedures. In the event of an accident at the test site, the following procedures will be followed:

(a) The senior supervisor at the scene of an accident will direct appropriate first aid. Caution will be exercised to prevent aggravation of an accident-related injury.

(b) Kirtland Air Force Base Hospital Ambulance Service will be immediately notified by calling Extension 110. The nature of the accident, including apparent condition of injured personnel and the location of the test site, will be reported to the medical personnel. The test director or, in his absence, the Senior Supervisor, shall determine whether to attempt transfer of the injured to a hospital or to request emergency ambulance support.

(c) The Test Director or, in his absence, the Senior Supervisor, shall determine the seriousness of the accident. If the accident is not serious enough to require emergency hospitalization or ambulance service, the injured person will be taken to a doctor or hospital by normal means of transportation.

f. First Aid. An adequate supply of first-aid items will be maintained at tne site. These items will be properly stored and periodically inspected to ensure their adequacy in case of an emergency.

g. Fire Prevent ion Reporting and Emergency Procedures. This paragraph defines the responsibility for fire prevention and reporting procedures related to the test.

(1) Responsibility. The Test Director will be responsible for the implementation of the procedures established by this plan. All on-site personnel must be completely familiar with these procedures to ensure proper response to an emergency.

(2) Fire Prevention Procedures. The procedures listed below are to be followed in an effort to reduce chances of an uncontrolled fire.

(a) Three portable fire extinguishers will be at the test site.

(b) The Test Director shall instruct all personnel on the procedures to follow in case of fire, and the location and use of available fire extinguishers.

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APPENDIX D

PENETRATOR TOOL

60-DAY EVALUATION QUESTIONAIRE

Evaluation of the penetrator tool by those actually operating the tool under field conditions is a crucial component of the overall program. Feedback from firefighting personnel is vital to the improvement of the tool and the safety of its user.

Answer each question fully and in detail. Include any comments on changes or improvements necessary to the operation of the tool.

If additional space is needed, mark another sheet of paper with the appropriate topic and question number and continue your response as fully as needed.

Thank you for your complete attention and cooperation.

Penetrator Tool - 60-Day Evaluation Questionaire

A. High Pressure Cylinders

1. What problems did you have with the high-pressure cylinders?

2. Were there any leaks detected in the cylinders? If so, where were they and what was done to stop them?

3. Did the cylinders charge properly? If not, what was the difficulty and solution?

4. Other problems or recommendations; be specific.

B. Regulator

1. Were any leaks detected in the regulator? If so, where were they and what was done to stop them?

2. Was any damage to the sealing surfaces noticed? If so, what type of damage and under what circumstances did it occur?

3. Did the regulator remain where it had been set? If not, why not and what was done?

4. Other problems or recommendations; be specific.

C. Drill

1. Were any leaks detected in the oiler? If so, where were they and what was done to stop them?

2. What difficulties were present while filling the oiler?

3. If the drill stalled during use, under what conditions did this occur? What changes were made to avoid a repetition of this occurrence?

4. Was any movement between the holder and tool body noticed? If so, how severe was it and under what conditions did it occur?

5. Other problems or recommendations; be specific.

D. Drill Bit

1. In what circumstances did dulling or breaking of the cutting edge occur?

2. Did the bushing show excessive wear? If so, after how much use? Was the wear connected with any unexpected event? Explain.

3. Did the clip hold the bushing properly? If not, under what conditions did it fail?

4. What difficulties were present when setting the bushing to bit clearance? What adjustments were made?

5. Other problems or recommendations; be specific.

E. Tool Body

1. Was there damage to the penetrator tip? If so, how did it occur?

2. Were any leaks detected in the seals within the tool body? If so, where did they occur and what was done to stop them?

3. Did the valve controlling the agent work properly? If not, under what conditions did it fail and what was the nature of the failure?

4. Was there any damage to the handles? If so, what caused it?

5. How did the location of the handles aid or hinder in maneuvering the tool?

6. Other problems or recommendations; be specific.

F. Training

1. What training did you receive on the use of the penetrator tool?

2. When training was completed, were you confident in the use of the tool?

3. What areas require specialized or more detailed training?

4. Did the weight of the tool cause problems during training? If so, what were the problems and were they overcome after you became familiar with the tool?

5. How was the tool attached to the fire truck? Was it secure? Was it convenient?

6. Other problems or recommendations; be specific.

G. Safety

1. What standard safety precautions were used when operating the penetrator tool? Were they adequate?

2. Were there any accidents or major damage while using the tool? If so, explain the event in detail.

3. What additional safety precautions were taken? Were they effective?

4. What new areas of concern for safety were discovered while using the tool?

APPENDIX E

RESULTS OF 60-DAY EVALUATION

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A. HIGH-PRESSURE CYLINDERS

1. What problems did you have with the high-pressure cylinders?

A. None.

B. The current air bottle is sufficient for short operation; however, should a longer operation be needed, recommend the use of approximately 50-feet hose and regulator to come off the one hour S.C.B.A. that are in use today, 4500 - 5000 lb/ins^2

C. None.

D. No problems were encountered with the cylinders with the following exception. The cylinders are considered too small for adequate storage of compressed air for complete penetration of the test aircraft skin (F-4S). Average 35 seconds of compressed air storage prior to depletion of power source (unsafe). Tool works well with continuous unlimited air supply.

E. No problems were encountered with the cylinders; however, the cylinder's air supply was depleted very fast. The cylinder air supply depletion time was recorded at 38 seconds.

F. The cylinders are too bulky and not enough volume.

G. Cylinder only l.sts 38 seconds. One electrical section on the nose of an F-4 ALC took 55 s.conds to drill into.

H. None.

I. Not large enough.

J. None.

K. Not enough air. Should have a min of 50-75 cubic feet of air.

L. The self-contained high pressure air supply was found to be inadequate. Could only drill about four holes through single panel thin aircraft skin. (Providing that the holes were drilled in a proper location and no obstructions were encountered during drilling) Note: May be difficult on unfamiliar aircraft, on fighters were drilling into intakes may be necessary, or where darkness may hinder the operator from finding a prime location to drill.

M. Not enough air.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. Need a larger cylinder bottle to do a complete job.

U. Did not last long enough.

V. None.

2. Were there any leaks detected in the cylinders? If so, where were they and what was done to stop them?

A. None.

B. No.

C. No.

D. No leaks were encountered.

E. There were no leaks detected.

F. No leaks were detected.

G. No.

H. None.

I. None.

J. Not to my knowledge.

K. None.

L. No. Hand tight was found to be adequate when connecting the high pressure hose and regulator to the bottle. Note that if a wrench is used damage to the O-ring seal may occur, as happens many times with SCBA when the high pressure hose is over-tightened.

M. None.

N. Not enough air.

O. Not enough air.

P. None.

Q. None.

R. None.

S. No.

T. No leaks.

U. No.

V. None.

3. Did the cylinders charge properly? If not, why not and what was done to correct the problem?

A. No problems.

B. Yes.

C. Yes.

D. No problems encountered.

E. Recharging the cylinder was conducted during the evaluation; there were no problems.

F. The cylinders charged properly, but the operation was very slow.

G. No problems encountered in recharging.

H. Yes.

I. None.

J. Yes.

K. Not answered.

L. N/A

M. Yes.

N. Yes.

O. Yes.

P. Yes.

Q. Yes.

R. Yes.

S. No.

T. Yes, cylinder charged properly.

U. No.

V. Yes.

4. Other problems or recommendations; be specific.

A. None.

B. None.

C. None at this time.

D. Current storage capacity of the high-pressure air bottle was inadequate to meet skin penetration on test aircraft (F-4S). This poses a danger to crash rescue personnel and potential aircraft occupants. The system works well with a continuous unlimited air supply. An average of 50-seconds was required to gain entry to engine compartment and apply agent on test aircraft (F-4S). Fifty test holes were drilled on test aircraft with actual agent application.

E. The penetrating tool seems bulky and somewhat heavy in weight to smaller personnel which made it difficult to handle and control the tool. Removing the cylinder, rear handle and the use of external air supply makes the tool easier to handle.

F. The unit is used best with the air supply from a mobile unit.

G. Recommend larger cylinders be employed and carried on a back pack rather than be attached directly to the penetrator.

H. None.

I. Air supply only good for one maybe two holes. Odds are that one hole you drill won't be in the right place.

J. N/A.

K. Yes.

L. It is recommended that another or an alternate air supply be readily accessible. (The tool could easily embarrass the operator with the self-contained air supply.)

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. Not answered.

U. Stronger drill motor.

V. None.

B. REGULATOR

1. Were any leaks detected in the regulator? If so, what was done?

A. No leaks detected.

B. No.

C. No.

D. No.

E. No leaks were detected.

F. No leaks were detected.

G. No.

H. None.

I. None.

J. None.

K. None.

L. Yes. The manual release for the relief valve was accidentally tripped on several occasions. It is recommended that a screw-out or pitcock type manual release be used instead of a needle valve.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. No, there were no leaks detected.

U. No.

V. None.

2. Was any damage to the seal surface noticed? If so, what type of damage and under what circumstances did it occur?

A. No damage noticed.

B. No.

C. No.

D. No problems were encountered.

E. No damage was noted.

F. No damage.

G. No.

H. None.

I. None.

J. None.

K. None.

L. No damage was noticed.

M. No.

N. No.

O. No.

P. Yes.

Q. No.

R. No.

S. No.

T. Not answered.

U. No.

V. No.

3. Did the regulator remain where set? If not, why not and what was done?

A. No problems.

B. Yes.

C. Yes.

D. The regulator did not create any problems even with continuous use by hard charging Marines. It is recommended that after each use, the lock nut on the regulator be checked. Continuous vibration may allow the lock nut to unfasten and cause the slotted adjusting screw to back out.

E. There were no problems with keeping the regulator set.

F. Regulation set OK as long as it was level.

G. Yes.

H. Yes.

I. OK.

J. Yes.

K. Yes.

L. To my knowledge the regulator was never tested.

M. Yes.

N. Yes.

O. Yes.

P. Yes.

Q. Yes.

R. Yes.

S. No.

T. Yes.

U. N/A.

V. Yes.

4. Other problems or recommendations; be specific.

A. None.

B. None.

C. None at this time.

D. For cost-effective maintenance on this equipment it is recommended that key crash rescue personnel be factory trained (available through U.S. Diver/Scott/Survive Air distributors) on repair of regulators. Some crash crews already have such programs established. Additionally, consider increasing operating pressure at regulator to speed up drill, possible decrease in time and force required to operate drill.

E. It is recommended that when this type of regulator is used, some type of marking system should be implemented to ensure proper setting of the regulator pressure.

F. None.

G. No problems with the regulator.

H. Not answered.

I. May need regulator set a little higher.

J. None.

K. Not answered.

L. That a gauge be placed on the low-pressure side of the regulator.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. Not answered.

U. N/A.

V. None.

C. DRILL

1. Were any leaks detected in the oiler? If so, where did they occur and what was done to stop them?

A. No leaks detected.

B. No.

C. No.

D. No leaks or problems were encountered.

E. No leaks or problems encountered.

F. No.

G. No.

H. No.

I. No oiler on this unit.

J. None.

K. N/A

L. No leaks were detected; oil was, however, found on the shaft of the drill bit where it fits into the drill chuck.

M. No.

N. No.

O. No.

P. No.

Q. No.

R. No.

S. No.

T. No.

U. No.

V. None.

2. What difficulties were present while filling the oiler?

A. None.

B. No.

C. None.

D. No difficulties were encountered.

E. No difficulties were encountered.

F. Did not do.

G. No need to fill the oiler during entire evaluation period. Approximately 6 hours during a 3-day period.

H. Not answered.

I. N/A.

J. None.

K. N/A

L. N/A.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. N/A.

U. None.

V. None.

3. If the drill stalled during use, under what conditions did this occur? What changes were made to avoid a repetition of this occurence?

A. The drill often stalled if it did not go into the hole straight.

B. No.

C. Did not stall.

D. The SPAAT has a tendency to stall when confronting an obstruction, at low air pressure, or when drilling at an angle. SPAAT will not penetrate non-aluminum surface and severely binds when not maintained on a straight course. Low air pressure reduces all system qualities. Maintain straight course and do not try and drill through ribs, steel or other nonaluminum hard surfaces.

E. The penetrating tool stalled when the tool's air supply became inadequate, when the tool penetrated into an obstruction or drilled in at an angle. The penetrating tool will not penetrate nonaluminum surfaces. The tool also had very severe problems with binding whenever a straight course wasn't maintained. This caused some personnel to lose control. It was noted that injury could occur when this happens.

F. The drill stalled when the pressure started to decrease and when the bit was in a bind.

G. No stallings.

H. Not answered.

I. If stalled normally too much pressure was being exerted by operator. Corrected by not forcing drill.

J. If you caused a bind the drill would sometime bog down slightly. Also some metal caused drill to slow. A more powerful drill would be better adopted for all applications.

K. Stalled while drilling in hardened metal. Repositioned angle of the drill.

L. Yes the drill stalled during use, repeatedly, just at the point where the bit broke through the aircraft skin. If once the bit breaks through the skin, force pressure is released the bit will cut through the skin and the bit will not stall.

M. No.

N. No.

O. Yes.

P. No.

Q. No.

R. No.

S. When I put pressure on the tool against the A/C it stalled. To get through that part of the A/C I didn't put as much pressure on it and it didn't stall but I needed more air pressure.

T. Drill did not stall.

U. When you push too hard on the drilling surface. Less pressure on drill.

V. No.

4. Was any movement between the holder and tool body noticed? If so, how severe was it and under what conditions did it occur?

A. None.

B. No.

C. No.

D. No movement or problem with holder and tool body observed.

E. No difficulties were encountered.

F. No movement was noticed.

G. No.

H. No.

I. None.

J. None.

K. Firefighter lost his grip while drilling under the aircraft in an upward angle. Sent in a second firefighter to assist.

L. No movement was noticed.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. No.

U. Very little.

V. None.

5. Other problems or recommendations; be specific.

A. None.

B. None.

C. None at this time.

D. It is recommended that the drill be set at a higher PSI rating to increase drill revolution speed and cutting ability. Reduction in cutting/penetration time essential.

E. It is recommended that the psi for the drill be set higher. This will increase the drill revolution speed and cutting ability. The cutting and penetrating time would greatly improve.

F. None.

G. Oiler is subject to breakage in an aircraft carrier environment.

H. Not answered.

I. None.

J. None.

K. Not answered.

L. "Shorter Please".

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. Not answered.

U. Not answered.

D. DRILL BIT

1. In what circumstances did dulling or breaking of the cutting edge occur?

A. The edge remained sharp; however, only soft materials were cut.

B. None.

C. None.

D. Dulling of the cutting edge occurs with multiple use, attempting to cut through nonalum' um surface; i.e., ribs, aircraft engine compartment reinforcement pane or dropping cutting bit on the floor. No breakage occurred during test period.

E. Breakage and dulling did occur on the drill bit. The breakage occurred when the tool was used improperly on the test aircraft. The bit also became dull after cutting 50 holes in a C-1 aircraft. The bit was also chipped during one test after hitting an obstruction. It is recommended that the bit be constructed of a more durable type metal.

F. No broken bits; however, the bit cutting edge would build up with metal from aircraft skin.

G. Drill bit chipped while being forced into the fuselage of the F-4 aircraft.

H. Cutting edge chipped when hard metal inside A/C was encountered.

I. Drilling occurred only after several (100 or more) holes. Tip of bit chipped after 2-3 holes.

J. When it was dropped on the ground, minor chip only.

K. Hardened metals.

L. Only through excessive use did dulling occur.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. Use against thick skin and or frame.

T. No breaking or dulling.

U. Going through thick skins.

V. None.

2. Did the bushing show excessive wear? If so, after how much use?

A. No excessive wear noted.

B. No.

C. No.

D. No excessive wear noticed.

E. No excessive wear was noticed.

F. No wear on bushing; not used enough to evaluate.

G. No.

H. No.

I. No.

J. None really noted.

K. No.

L. No bushing wear noted.

M. No.

N. No.

O. No.

P. No.

Q. No.

R. No.

S. No.

T. No.

U. No.

V. No.

3. Did the clip hold the bushing properly? If not, under what conditions did it fail?

A. Did not fail.

B. Yes.

C. Yes.

D. No failure of the clip or bushing obvious during test period.

E. There was obvious clip failure noticed, which occurred when the tool was improperly forced into the aircraft skin. The clip was easily replaced.

F. Yes.

G. Yes.

H. Yes.

I. No problem.

J. Yes.

K. Yes.

L. The clip held the bushing properly in place.

M. Yes.

N. Yes.

O. Yes.

P. Yes.

Q. Yes.

R. Yes.

S. Yes.

T. Yes.

U. Yes.

V. Yes.

4. What difficulties were present when setting the bushing to bit clearance?

A. No difficulties, but feel that a gauge would be better to properly adjust bit.

B. None.

C. None.

D. When adjusting the bushing bit clearance it is necessary that two men perform the task. The tool must be positioned on its tip and adjusted by lifting the main body until the proper clearance is made. If you lay the tool on its base, as it is recommended, there is a strong possibility that the user will cut himself with the blade tip or barrel assembly (Safety Hazard).

E. There were no difficulties setting the bushing to bit clearance. However, caution must be taken or injury to the user's hand may occur from the cutting tip. It is recommended that a cover be provided for the cutting tip to prevent injury and also provide protection for the cutting tip.

F. Too much time was involved in setting the bushing.

G. No difficulties; changed three bits provided with the tool.

H. None.

I. No problems. All screws had to be checked for tightness periodically.

J. None.

K. None.

L. N/A.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. None.

T. None.

U. None.

V. None.

5. Other problems or recommendations; be specific.

A. None.

B. None.

C. None at this time.

D. Possible research into wider diameter bit for larger penetration or more cutting edges of bit itself (slow penetration qualities at existing maximum discharge air pressure).

E. No other recommendations.

F. None.

G. Recommend a more durable bit be provided.

H. Not answered.

I. Maybe safety wire screws?

J. None.

K. Not answered.

L. It is recommended that a piece c° plastic pipe approx 18 1/2" or 19" be slipped over the entire drill bit and shaft. During storage to protect the bit, and should only be removed prior to dulling to protect the operator and others in the proximate area from accidental run of the drill motor or discharge of agent.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. Not answered.

U. Not answered.

V. None.

E. TOOL BODY

1. Was there damage to the penetrator tip? If so how did it occur?

A. No damage.

B. No.

C. No.

D. What appeared to be normal wear from multiple drillings was present.

E. There was damage to the tip. This damage occurred when the tool was forced into the aircraft skin improperly. The retaining clip broke and the tip came off. Normal wear was noticed also on the drill bit and cutting tip. The tip also received a chip in it during on this phase. The chip in the cutting tip was apparently from some type of obstruction in the aircraft.

F. No damage.

G. See Item D(1.).

H. No.

I. Yes. Unknown exactly when occurred.

J. Small chips occurred when drill bit was dropped during changing.

K. Not answered.

L. No damage noted.

M. No.

N. No.

O. No.

P. No.

Q. No.

R. No.

S. No.

T. No.

U. Dulling very quickly.

V. No.

2. Were any leaks detected in the seals within the tool body? If so, where did they occur and what was done to stop them?

A. No leaks.

B. No.

C. No.

D. No leaks were detected during test period.

E. No leaks were detected.

F. No leaks.

G. None.

H. No.

I. None.

J. None.

K. None.

L. No leaks noted.

M. No.

N. No.

O. No.

P. No.

Q. No.

R. No.

S. No.

T. No.

U. No.

V. No.

3. Did the valve controlling the agent work properly? If not, under what conditions did it fail and what was the nature of the failure?

A. Performed well.

B. Yes.

C. Yes.

D. No problem with the agent control valve identified during test period.

E. The agent control valve worked properly.

F. Not evaluated.

G. No problem encountered.

H. Yes.

I. None.

J. Yes.

K. Yes.

L. Yes, although I only observed agent discharge on one occasion no failure was noticed.

M. Yes.

N. Yes.

O. Yes.

P. Yes.

Q. None.

R. None.

S. None.

T. None.

U. Worked well with halon.

V. Yes.

4. Was there any damage to the handles? If so, what caused it?

A. No damage.

B. No.

C. No.

D. No damage to handles occurred during test period.

E. No damage to the handles occurred.

F. Not evaluated.

G. None.

H. No.

I. None.

J. None.

K. No.

L. No damage was noted.

M. No.

N. No.

O. No.

P. No.

Q. No.

R. No.

S. No.

T. No.

U. No.

V. No.

5. How did the location of the handles aid or hinder in maneuvering the tool?

A. Handles are well located and made the tool easy to control.

B. Location good.

C. Location good.

D. The position of the handles for insertion of the SPAAT was good, although, when trying to remove the tool, users had a tendency to pull on the drill pistol grip rather than the handle. Possible consideration into additional reinforced handle for removal.

E. The rear handle and the air bottle bracket made it difficult to operate. Once they were removed from the penetrator it was easier to control and operate.

F. Not evaluated.

G. Handles are a necessity in operating the tool.

H. The handles could be smaller, requiring less storage room.

I. No problems.

J. None.

K. Not answered.

L. The location of the handles aided the use of the tool and allowed more than one person to assist in operating the drill.

M. Didn't really help at all.

N. Didn't really help at all.

O. Didn't really matter.

P. Didn't matter.

Q. Didn't matter.

R. Okay.

S. None.

T. Handles handled tool easily.

U. They were in good placement.

V. Handle need to be moved to another location.

6. Other problems or recommendations - be specific.

A. None.

B. Recommend that part #40 (adapter on quick connector) have female threads the same pattern as part #22 (the one that screws into the SPAAT). These are the threads that are currently on all our Halon 1211 and 1" booster lines. As it is right now, we are unable to use the quick disconnect coupler.

C. None at this time.

D. Installation of additional handle at pistol grip position may be helpful during removal process.

E. There was difficulty in removing the tool once the aircraft was penetrated. It is recommended that an additional handle be placed at the hand grip area. This would allow the tool to be removed from the aircraft with less difficulty.

F. None.

G. None.

H. Issue unit with a longer hose and back pack Scott type & larger air cylinder.

I. A protective removable cover for the tip would be a good safety improvement.

J. None.

K. Handles take up a lot of room in truck storage. With limited space on CFR vehicles the large handles make it hard to store for a quick response.

L. Not answered.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. Not answered.

U. Not answered.

V. None.

F. TRAINING

1. What training did you receive on the use of the penetrator tool?

A. In-depth classroom training included history, assembly and hands-on practical training. Representative from Ametek was present to answer questions. We are in the process of making a training video of the SPAAT, which will show assembly, maintenance, and use of the tool.

B. Classroom, live fire drills using A-4 aircraft.

C. Classroom and practical.

D. The New Mexico Engineering Research Institute provided four hours of classroom and four hours of practical application field training on operation and maintenance.

E. Training was provided by New Mexico Engineering Research Institute engineer. The training consisted of 4 hours of classroom, 4 hours of practical application and field training on operation and maintenance.

F. Film, classroom lectures, hands-on training, and practical exercises.

G. Received approximately 3 hours of classroom training on the complete nomenclature of the tool.

H. Factory representative and manual.

I. Classroom from manual and approximately 3 hours in the field.

J. We penetrated the skin on SH2F, F-4, Wooden Pallet, Sheet Metal, Diamond Plate (steel).

K. First class was from Mr. Plugge. Bi-weekly hands-on training sessions.

L. Introduction of the tool, some hands-on use and a demo of halon discharge.

M. Proper Use, OJT with F-4.

N. Use on OJT F-4.

O. F-4.

P. OJT.

Q. OJT.

R. Proper use and OJT.

S. Drilling on Hilo and A/C.

T. Instructor/on hands.

U. Classroom & Hands-on.

V. Use OJT with F-4, hello.

2. When training was completed, were you confident in the use of the tool?

===

A. Yes.

B. Yes.

C. Yes.

D. The operation and maintenance training that was provided was adequate for its purposes. A continuous source air supply and higher drill speed would increase the personnel confidence in the tool's ability to drill into various aircraft skins.

E. More than half of the personnel that used the penetrator tool were not confident with the tool because of the time it took to drill a hole into an aircraft, the speed of the drill which was slow and depletion of air supply which was 38 seconds. If the recommended modifications outlined earlier in this evaluation are applied to the penetrator tool, personnel may become confident in the tool.

F. Yes.

G. Yes.

H. Yes.

I. Yes with some in-house modifications. Larger capacity air cylinder was adapted to drill. Cylinder is now carried on backpack.

J. Yes.

K. Yes.

L. Somewhat confident in the use of the tool but not very sure of the capability of this tool in coordination with the P-17 and P-19 CFR vehicle which only carry 200#-250# halon, also what is the water flow capacity of the SPAAT.

M. Yes.

N. Yes.

O. Yes.

P. Yes.

Q. Yes.

R. Yes.

S. In some conditions I would be but not all.

T. Yes/no.

U. Yes.

V. Yes.

3. What areas require specialized or more detailed training?

A. Maintenance of the tool.

B. More practical use.

C. Practical.

D. A special class on how to repair/sharpen the drill bits would add to the maintenance aspects, also specialized training in repair of the air flow regulator.

E. Detailed training may be required for repair and instruction on how to sharpen the cutting tip and should be included in the maintenance. Key personnel should have some knowledge of repairing items such as the regulator and the in-line lubricator. This may require specialized training.

F. More practical exercises.

G. None.

H. Not answered.

I. 90% of holes we drilled were in an F-4 J. This required actual penetration of 2 layers of skin. Hole location is critical.

J. Adding more volume to air cylinder.

K. The configuration that will be used at different location.

L. A hands-on timed start to finish drill, removing the tool from the apparatus, setting up tool to drill, drilling the hole, hooking up the hand line and discharging agent.

M. More realistic training with tool.

N. More training.

O. More training.

P. Not answered.

Q. More training.

R. None.

S. Not answered.

T. Bigger motor, to turn bit.

U. Hands-on training.

V. Realistic training.

4. Did the weight of the tool cause problems during training? If so, what were the problems and were they overcome after you became familiar with the tool?

A. Only problem was weight, and this was discussed in section E.6.

B. No.

C. No.

D. The tool weighs approximately 15 pounds and posed no major problem to users during test period. Some of the small firefighters and women had a little problem removing the tool after penetrating the aircraft skin.

E. The tool weighed 25 pounds totally outfitted. The weight of the tool did cause problems for smaller personnel. However, with the removal of the cylinder assembly, regulator and rear handle, the tool became lighter and much easier to operate.

F. Yes. This problem was solved by removing the bottle and bracket.

G. The weight problem was initially caused by the high pressure cylinder. Once it was removed and ships air was utilized, it became easier to operate.

H. No.

I. Weight was reduced by using alternate air source on backpack.

J. No.

K. Yes. With the air cylinder attached this problem was overcome by attaching the drill to an air pack bottle.

L. I don't think that the weight of the tool has caused as much of a problem as the length of the tool. Even on a ditched aircraft such as a 727 a ladder would need to be used to penetrate the passenger compartment. The tool I thought was very difficult to operate at any level above the chest without the help of another operator.

M. No.

N. No.

O. No.

P. No.

Q. None.

R. No.

S. No.

T. No.

U. No.

V. No.

5. How was the tool attached to the fire truck? Was it secure? Was it convenient?

A. Tool was not attached to truck.

B. Carried on the tail mounted in compartment. Secure.

C. In compartment. Secure. Convenient.

D. The SPAAT was attached to the handline of the 500-gallon Halon 1211 extinguisher or the AS32P-19 crash vehicle. The air line was attached to a separate nitrogen cylinder external to the truck. Present design of the P-19 does not make it convenient to mount the tool to the existing system.

E. The penetrator tool was attached to the A/S32P-19A crash vehicle's 500 pound Halon 1211 unit. The air supply was from a nitrogen cylinder located on a rescue/support vehicle. Agent flow was conducted with the use of Halon 1211 and AFFF (light water) but there was no actual fire extinguishment conducted.

F. The tool was placed in a fiberglass box lined with foam.

G. No fire truck used.

H. Stored in Compartment of truck. No. Yes.

I. Carried in Asst. Chief T.A.U. command vehicle in standard compartment.

J. Straps.

K. At this time, it is secured in a compartment. In the future, when modifications are made to the vehicles it will be much more convenient.

L. Once again the length of the tool and the handles mounted in a fire position make it extremely difficult to store on fire apparatus assembled and ready to use. It is neither secure or convenient by any means.

M. Was not attached.

N. Didn't use truck.

O. Was not attached.

P. Was not attached.

Q. Was not attached.

R. No.

S. Yes.

T. N/A.

U. N/A.

V. Was not attached.

6. Other problems or recommendations; be specific.

A. None.

B. None.

C. None at this time.

D. The training class should be more detailed on how to sharpen the penetrator bits after use. Also, more detailed training on repair of the regulator should be provided. Finally, when actual practical application testing is performed, utilization of all types of test aircraft hulls is highly recommended. We could only test the tool on our F-4'S.

E. There was a problem with storage for the penetrator. The tool could be carried on major CFR vehicles; however, it must be taken completely apart, then there's the possibility of a lot of lost time putting this type of tool into service. Trying to store the tool fully assembled is impossible because of the tool's size.

F. None.

G. No answer written.

H. Not answered.

I. Ribs in aircraft must be avoided. This is difficult sometimes and is more an operator problem, not a tool problem.

J. None.

K. Side loop handles should be smaller. The air supply should be between 50 and 75 cubic feet and carried on a sling type system with the drill on a 6 ft. hose. This would allow one or two man operation.

L. Possibly a shorter shaft and bit for military aircraft, or folding handles.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. None.

T. Not answered.

U. Not answered.

V. None.

G. SAFETY

1. What standard safety precautions were used when operating the penetrator tool? Were they adequate?

A. Yes. Gloves, eye protection and aural suppressors. Good footing is also very important.

B. Full turn out gear. Adequate.

C. Full turn out gear.

D. Each trainee was outfitted with full proximity suits. They always worked as a pair for safety reasons. When fighting the actual test fires, a back-up man with a charged handline off the firefighting truck was provided as a safety man. All safety precautions were adequate.

E. All personnel using the penetrator tool wore head, hand and eye protection. There were no actual test fires. However, some personnel were outfitted with full proximity suits (bunker gear).

F. Normal power tool safety precautions.

G. Safety goggles for eye protection.

H. Goggles, gloves.

I. Goggles & gloves were adequate.

J. Eye protection, turnout glare, gloves, ear protection.

L. Flight deck cranial, and goggles, were found to be for the most part adequate.

M. All Navy Safety Standards.

N. All safety precautions.

O. All safety standards.

P. All safety standards.

Q. Normal safety precautions.

R. Ear, eye, gloves.

S. Goggles, yes.

T. Goggles/yes.

U. Goggles, gloves.

V. Normal Safety Standards.

2. Were there any accidents or major damage while using the tool? If so, explain the event in detail.

A. No accidents.

B. No.

C. No.

D. No accidents were reported during the training sessions, and no major damage to the tool was reported.

E. No accidents occurred. However, there was a major damage to the tool. The retaining clip was broken when one of the test personnel forced the tool into the surface. The clip was replaced very easily. However, when a situation like this occurs during an actual incident, the penetrator becomes useless.

F. None.

G. None.

H. None.

I. No major problems.

J. None.

J. None.

K. None.

L. No accidents reported.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. No.

T. No.

U. No.

V. None.

3. What additional safety precautions were taken? Were they effective?

A. None needed.

B. Charge 1 1/2 inch hose line in position during live fire drills.

C. None.

D. Attaching the tool to a constant air source is highly recommended. Always work in twos and have an additional safety man standing by.

E. Working as a team is recommended, also the use of a constant air supply.

F. None.

G. Not answered.

H. Not answered.

I. None.

J. Personnel attending classes were stationed just far enough back to have a secure area.

K. None.

L. Gloves should be used when discharging agent.

M. None.

N. None.

O. None.

P. None.

Q. None.

R. None.

S. None.

T. None.

U. No.

V. None.

4. What new areas of concern for safety were discovered while using the tool?

A. Using caution not to drill into wiring, LOX, fuel tanks, etc. Also location of passengers.

B. None.

C. None.

D. The tool should be equipped with a shorter barrel for penetrating small aircraft. The barrel provided with the test SPAAT tool was considered too long for attacking fighter aircraft internal fires. Additionally, the self-contained high pressure air bottle is considered too small for practical use. Unless the SPAAT tool is outfitted on a special vehicle such as the P-13, it is considered too bulky and not really practical for use on the AS32P-19.

E. The safety of crew and passengers aboard the aircraft. When halon is injected into the area of an aircraft where crew and passengers are located, the halon may cause a serious respiratory problem for the occupants. The barrel of the penetrator should be shorter for fighter type aircraft.

F. None.

G. The possibility of drilling into high pressure air or hydraulic components and high voltage electrical circuits.

H. Not answered.

I. The tip must be carried in the tool for time's sake. A cover of some sort will be necessary to protect tip from damage and protect personnel when drill is not in use.

J. None noted.

K. Metal shavings.

L. As noted under Part D, Drill Bit question #5, a piece of plastic pipe slid over the bit and shaft.

M. No.

N. No.

O. No.

P. No.

Q. No.

R. No.

S. None.

T. None.

U. No.

V. No.

H. SUMMARY

A.

B.

C.

D. When a fire occurs in a confined area whether it be on an aircraft, vehicle or structure, gaining entry and applying agent to combat the fire must be quick and the firefighter must have confidence in the equipment he must use. The SPAAT as it is presently designed will work well if it is outfitted aboard a specialized vehicle such as the Air Force P-13, which is equipped with additional hose, constant air source, and storage compartments. The Marine Corps cannot afford the luxury of this additional space. The tool itself takes too long to put in service and is only effective cutting through aluminum skin and binds easily when hitting an obstruction. The drill speed seems to be too slow and an interchangeable barrel (shorter) is recommended for fighter aircraft. Comments from all test personnel indicate that the tool takes too long to cut through aircraft skin (no confidence). The same basic function can be accomplished with a crash axe and handline much faster. Before any large scale procurement is considered, more testing with the recommended modification outlined within the salient points should be undertaken.

Additionally, consideration should be given to outfitting the AS32P-19 with quick disconnect fittings on both Halon 1211 and AFFF handlines for use with the old penetrator nozzle that was standard equipment on the MB-5. This nozzle could be added to the SL-3 list of collateral equipment and would provide the same function as the SPAAT does for the Air Force. It can also be easily added to the compartment space on the truck with little modification.

E. Cabins, compartments, and confined type fire has always created somewhat of a problem with Crash Crew. We greatly appreciate the time and efforts of Technical Research. However, we have overcome this problem with the use of an axe and handline. There's also the trustworthy bayonet nozzle. These two methods still work just fine and appropriate personnel that were involved in this evaluation feel more confident with these methods of combatting interior fires. Test personnel indicated that the tool is too slow, bulky and not practical for them to use. There was also a problem of storage, setting the tool up and removing the tool from the aircraft as outlined in this evaluation. The tool did cut well with a constant air supply until it hit some obstruction. The bayonet nozzle out performed this tool on fighter aircraft. It took the bayonet nozzle less time to penetrate the aircraft. However, the penetrator out performed the bayonet nozzle on aircraft with wider or thicker areas of the test aircraft. The bayonet nozzle required someone with great strength to force the nozzle through. If the nozzle didn't go through the first time, it had to be removed and a second or third attempt had to be made.

Finally, more tests should be performed with the penetrator with the recommendation and modifications outlined in this evaluation. The Marines involved in this test evaluation indicate that the tool would not be beneficial for the Marine Corps at this point in time.

L.

M.

N.

O.

P.

Q.

R.

S.

T.

U.

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